The Causticaire Method for Measuring Cotton-Fiber Maturity and Fineness: Improvement and Evaluation

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SUMMARY AND CONCLUSIONS

Percentage of mature fibers in a sample of cotton, as a measure of fiber maturity, has constituted the weakest link in cotton-fiber technology for many years. The use of the generally recognized standard method for determining that measure of fiber maturity constitutes the bottleneck in most cotton-fiber research and testing programs of today.

Criticism of the prevailing test for maturity stems from the fact that it is tedious, laborious, and time-consuming to perform; that the required procedure of classifying all fibers of a sample, including many borderline cases, into two categories of cell-wall thickness is highly susceptible to the personal equation; that comparable results are obtainable only by carefully trained and experienced operators; that the level of such maturity ratings frequently vary between operators, sometimes even between operators who are well trained and experienced; and that such maturity evaluations have not proved to be an effective measure for properly evaluating the contribution and importance of that factor of cotton quality to processing performance and quality of manufactured product.

All evidence available at present indicates that the development of the new Causticaire method of test for evaluating cotton-fiber maturity and fiber fineness constitutes a notable step forward in fiber technology. The Causticaire method is, by principle and operation, unique in that only a combination of Micronaire readings for raw cotton (untreated) and the same cotton treated with sodium hydroxide (40 Tw) is required for deriving the two measures of cotton-fiber maturity and fineness.

The Causticaire readings for treated cotton samples provide a good basis for the calculation of fiber weight per inch and degree of cell-wall development because the fiber cross sections tend to become circular upon treatment with the sodium hydroxide solution and all surface areas of the fibers are exposed. Causticaire fineness and maturity values, therefore, proportionally represent all gradations in fiber weight per inch and cell-wall development from fiber to fiber throughout a sample, and from base to tip of individual fibers.

Of first and foremost consideration is the fact that the Causticaire method has proved to be a more rapid and practical test of fiber maturity than has the standard maturity test in wide use today. No extra work is required to obtain the fineness value for a sample, except to make a simple calculation. Practically no personal equation is involved in the Causticaire method of test. Qualified but relatively inexperienced operators, by possessing only a minimum of instruction and merely exercising reasonable care, can obtain comparable results from the Causticaire test.

In the light of the findings presented in this report, as obtained from multiple correlation analyses representing 52 cottons selected to cover a wide range and general distribution of fiber fineness and maturity, and processed at one rate of card production (9-1/2 pounds per hour), the Causticaire method has furnished maturity values possessing considerably more significance toward nep-count of card web, yarn appearance, and yarn strength than has either percentage of mature fibers (standard method) or immaturity ratio (Arealometer). The Arealometer maturity measure proved to be somewhat better in those respects than did the standard maturity measure, but not as good as the Causticaire maturity measure.

The Causticaire method has been found to give more accurate, comparable, and significant evaluations of fiber maturity for cottons throughout the entire range of fiber maturity and fineness, particularly in the case of cottons possessing relatively large or small percentages of thin-walled fibers and of those possessing comparatively small or large values for fiber weight per inch, than has either the Arealometer or the standard maturity method. For more or less average cottons, however, the respective maturity and fineness values furnished by the Causticaire and Arealometer methods were in relatively good agreement.

Values representing the three fiber maturity measures, as furnished by the Causticaire, Arealometer, and standard method, have been compared and correlated.

Also, values representing the four fiber fineness measures, as furnished by the Causticaire, Arealometer, Micronaire, and array method, have been compared and correlated.

In terms of natural fiber properties and comparable textile processing, the disparity in certain correlation values obtained from different series of cottons and processing procedures used in this study is more apparent than real, as discussed in this report. Certainly, such reported differences are understandable and explainable, and in no sense conflict with or mitigate against the principal conclusions and recommendations set forth in this report.

A total of 159 correlation analyses were made in connection with this study. The results from only 43 correlation analyses, however, are presented in this report. A total of 894 cottons, including American upland, American Egyptian, Egyptian, Sea Island, Asiatic, and hybrid types, were used in the analyses reported herein.

A complete description of the Causticaire method of test is contained in this report, including essential accessory equipment, improved procedures, and formulas for calculating the values of maturity index and fiber fineness (weight per inch). Also, a reduced reproduction is shown of the new Causticaire scale for evaluating both cotton-fiber maturity and fineness, the scale of which is applicable to all botanical types of cotton having a fiber fineness (weight per inch) of less than 8.0 micrograms.

THE CAUSTICAIRE METHOD FOR MEASURING COTTON-FIBER MATURITY AND FINENESS: IMPROVEMENT AND EVALUATION

By Robert W. Webb and Samuel T. Burley, Jr., cotton technologists, Agricultural Marketing Service

INTRODUCTION

Limitations in the practical meaning and significance of percentage of mature and immature fibers for evaluating cotton-fiber maturity or degree of cell-wall development, as obtained by the standard method described in ASTM methods (4) 1/ and in Cotton Testing Service (22), have been generally recognized for a number of years. Webb and Richardson, in their 1951 report on neps (25), discussed various concepts and measures that have been advanced for the evaluation of cotton-fiber maturity and immaturity, and they pointed out certain shortcomings and weaknesses of the present standard measure of fiber maturity, whereby the fibers in a sample are counted after classification--on an arbitrary basis--into only two fiber-type categories; namely, mature and thin-walled.

Carpenter (6) recently made a comprehensive study on the evaluation of various ratios for classification of cotton fibers according to maturity. She concluded that, regardless of which ratio was used, the percentage value for maturity followed the same general pattern for all samples, except one sample which was consistently more mature for fibers included in neps than was its relative position for raw cotton. Her findings further indicated that the present standard ratio of 0.5 fiber cell-wall thickness in relation to lumen width is as valuable as any of the experimental ratios for determining maturity by the sodium hydroxide method, and that this ratio is easier to apply than the other experimental ratios which she tried.

On the basis of statistical values obtained from a comprehensive series of multiple correlation analyses over a period of years, Webb and Richardson (25) emphasized the urgent need for the development of a more effective and significant measure of fiber maturity as a basis for properly evaluating the importance of that factor of cotton quality to processing performance and quality of manufactured product. The development of the new Causticaire method of test for evaluating cotton-fiber maturity and fineness, as first announced by Burley and Bartmess in their preliminary report of 1952 (5) and as referred to in Textile World (3), constitutes a definite step forward in the effort to evaluate more properly cotton-fiber maturity.

The original Causticaire method described by Burley and Bartmess (5) had certain recognized limitations. Further study has resulted in the development of certain accessory equipment essential for allowing Causticaire tests to be made in greater volume, of improved procedures and more refined techniques for use in making the individual tests, and of a single Causticaire scale for the determination of both cotton-

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1/ Underscored numbers in parentheses refer to Literature Cited p. 48.

fiber fineness and maturity. The scale for determining cotton-fiber fineness and maturity was recently reported by the Department (24).

A comprehensive series of correlation analyses recently have been completed on the relationship existing between four alternative measures of cotton-fiber fineness and between three alternative measures of fiber maturity; on the relation and relative importance of the Causticaire, Arealometer, and standard maturity measure toward nep count of card web, appearance of 36s yarn and skein strength of 36s yarn; and on the relation and relative importance of Causticaire maturity and Causticaire fineness versus standard maturity and Micronaire fineness toward nep count of card web, appearance of 22s yarn, appearance of all yarn sizes spun, skein strength of 22s yarn, and count-strength product of all yarn sizes spun.

Findings from these analyses are given in this report. Similar findings of a supplementary nature also are shown for a group of cottons selected on the basis of graduated degrees of fiber fineness (weight per inch) and maturity throughout their available ranges, in order to permit evaluations based on an equal distribution of observations with respect to fiber fineness and maturity, and in an effort to explain certain disparities noted in results between the selected and unselected series of cottons.

This report supersedes the preliminary report (5) entitled " The Causticaire Method for Determining Cotton-Fiber Maturity and Fineness," published in August 1952.

SETTING OF THE PROBLEM

The need for a faster and simpler, yet accurate and dependable, method for evaluating cotton-fiber fineness prompted research workers, during the last 15 years or more, to study the possibility of adapting the air-permeability principle to the measurement of this fiber property, as reported by Fowler and Hertel (8) and by Sullivan and Hertel (18), (19). Several types of instruments have been developed for this purpose, each of which operates on the same principle and permits an evaluation of cotton-fiber fineness on a bulk or average basis from a prepared specimen composed of many fibers. In operation today at various laboratories in the United States and possibly elsewhere are four such instruments as follows:

1. "Permeameter," an adaptation of the Schiefer-Frazier Fabric Permeability Tester (13) for the evaluation of cotton-fiber fineness by Pfeiffenberger (12).

2. Kendall-Mills Porosity Meter, as developed by Elting and associates (7).

3. Micronaire fiber fineness tester, as conceived by Smith (15) of the West Point Manufacturing Company, developed through cooperation by the Sheffield Corporation (14), and covered in news release (2).

4. "Arealometer," as developed by Hertel and associates for evaluating cotton-fiber fineness, reported by Sullivan (17), and covered further in Spinlab Instruction Manual (16).

A comparative study of the performance and adaptability of the first three air-permeability instruments listed above was made recently by Lee and Hernandez (11) in the cotton laboratories of the Department of Agriculture in Washington. The "Arealometer," the fourth type of instrument, was not available for inclusion in that study. A comparison of the findings was made in that report not only for the measures of fiber fineness, as furnished by the three different instruments with the same series of cottons, but also for length-array fineness (weight per inch).

More recently, in line with the developments for testing cotton-fiber fineness, the need for a faster, simpler, more accurate and more dependable method for evaluating cotton-fiber maturity, or degree of cell-wall development, has led research workers to study the possibility of using the air-flow principle and available instruments for evaluating both fiber maturity and fineness in a sample of cotton simultaneously or in conjunction with each other. Two such instruments have received particular attention in this connection, namely, the "Arealometer" and the "Micronaire."

The method for evaluating cotton-fiber fineness and maturity by the "Arealometer" was developed by Hertel and Craven (10). A simplified description of the instrument, its operation, and method of testing, is given in the Instruction Manual for Spinlab Arealometer (Model 142) issued by Special Instruments Laboratory, Inc. (16). A brief synopsis is quoted from the manual, as follows:

" The Spinlab Arealometer is an air flow instrument for determining the fineness and maturity of raw cotton and other fibrous materials. The instrument measures the apparent surface area under two different compressions of an accurately weighed fiber sample. From the data obtained, fineness expressed in square millimeters per cubic millimeter, or simply reciprocal millimeters, may be known. In addition to the maturity or cross sectional shape of the fiber, the perimeter, the weight fineness, and the wall thickness may be calculated."

With the Micronaire tester, the basic procedure used in the Causticaire method for evaluating cotton fiber fineness and maturity was outlined by Burley and Bartmess (5) and the improved procedure is described in a later chapter of this report. The principal

features involved in this test are as follows: Micronaire readings are made on fluffed and blended samples of untreated cotton, and on the same cotton treated with sodium hydroxide (40 Tw), by use of a scale graduated to give air-flow measurements in index points from 10 to 110. This is an improved scale, the development of which will be described later in this report, and constitutes a change from the linear graduated scale referred to by Burley and Bartmess (5) in their preliminary report announcing the new Causticaire method. The formulas for calculating Causticaire fineness (weight per inch) and Causticaire maturity index are shown in the chapter entitled "Procedure of Testing by the Causticaire Method."

The new Causticaire method for evaluating cotton-fiber maturity and fineness is attracting considerable attention on the part of research workers at various laboratories in this country and abroad, as evidenced by the fact that comparative tests and studies already are under way at several other institutions. Insofar as known, however, no results have been published from those efforts, except by Alberts (1) at the Fiber Research Institute in Holland. The summary of his recent report reads as follows:

"In order to get a method for determining cotton-fiber maturity, being quicker as compared with those applied so far, the Fiber Research Institute T.N.O. has worked out the principle of the Causticaire method recently published by the U.S.D.A., Washington.

"The method developed takes considerably less time than other methods used; its reproducibility is better. Moreover, it can be carried out by laboratory personnel relatively untrained.

"Practice will prove how far the Maturity Index gives information on the spinning properties and the behaviour of cotton during dyeing."

IMPROVEMENTS IN THE CAUSTICAIRE METHOD

The Causticaire method for the evaluation of fineness and maturity of cotton fibers by the application of the air-permeability principle was described by Burley and Bartmess (5), in a preliminary report, entitled "The Causticaire Method for Determining Cotton Fiber Maturity and Fineness," published in August 1952. The method described involves the use of a commercially available instrument known as the Micronaire by which readings are obtained on a sample of cotton before and after treatment in a solution of sodium hydroxide (40 Tw). Subsequent to the findings published in the preliminary report, further research and development work resulted in the perfecting of a single Causticaire scale for use in measuring both fiber fineness and maturity of all botanical types of cotton having a fiber fineness (weight per inch) of less than 8.0 micrograms.

Revised Causticaire scale. The linear Causticaire scale described in the preliminary report was revised to provide more significant measurements of fiber fineness and maturity as based on results of empirical tests and statistical analyses of test results. The cottons used in those tests included various botanical types having a wide range of fiber properties. The revised Causticaire scale is graduated in index points from 10 to 110. Approximate airflow in cubic feet per minute can be calculated for index readings of 30 to 100 by use of the following formula:

$$\text{CFM} = (0.0236\ \text{Index}) - 0.20$$

The parts of the scale below 30 and above 100 are not closely related to airflow.

The calibration points on the Causticaire scale are at the same positions in the tube as those of the current standard calibration of the instrument. When calibrating the instrument with the two standard orifices, the revised Causticaire scale shows readings of 40 and 81 for the lower and upper calibration points, respectively. A reduced reproduction of the new Causticaire scale is shown in figure 1.

Causticaire fiber weight per inch as related to fiber weight per inch (array method). The Causticaire readings for treated cotton samples provide a good basis for the calculation of fiber weight per inch and degree of cell-wall development because the fiber cross sections tend to become circular upon treatment with the sodium hydroxide solution and all surface areas of the fibers are exposed. Causticaire fineness and maturity values, therefore, proportionately represent all gradations in fiber weight per inch and cell-wall development from fiber to fiber throughout a sample, and from base to tip of the individual fibers.

A correlation analysis of array weight-per-inch data representing 142 selected samples of cotton (including American upland, American Egyptian, Sea Island, Egyptian, triple hybrid, and Asiatic types) with Causticaire weight-per-inch values gave a coefficient of correlation of +0.976 with a standard error of estimate of ± 0.23. Figure 2 is a scatter diagram of the paired values for this series of cottons.

Based on results from the correlation analysis referred to above, a formula was developed for calculating weight per inch from the Causticaire readings, as listed under item 8 in the next chapter entitled "Procedure of Testing by the Causticaire Method." The samples of cotton, which served as the basis for that formula, varied widely in fiber fineness and in maturity, ranging from 1.8 to 8.1 micrograms per inch by the array method and from 24 to 88 maturity index values.

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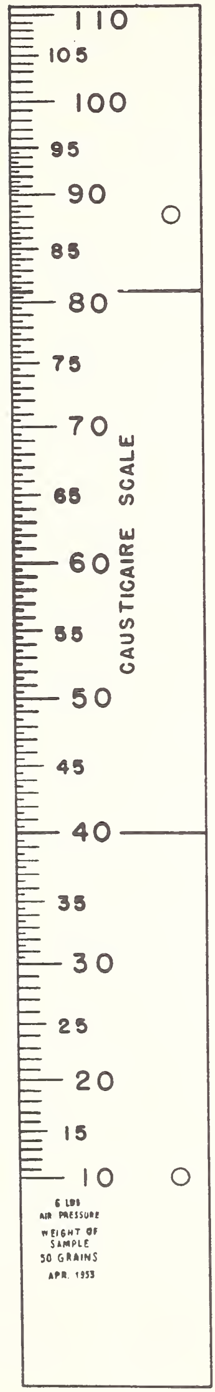

Figure 1.—Reduced reproduction of the new Causticaire Scale for evaluating cotton-fiber fineness and maturity by use of the Micronaire instrument.

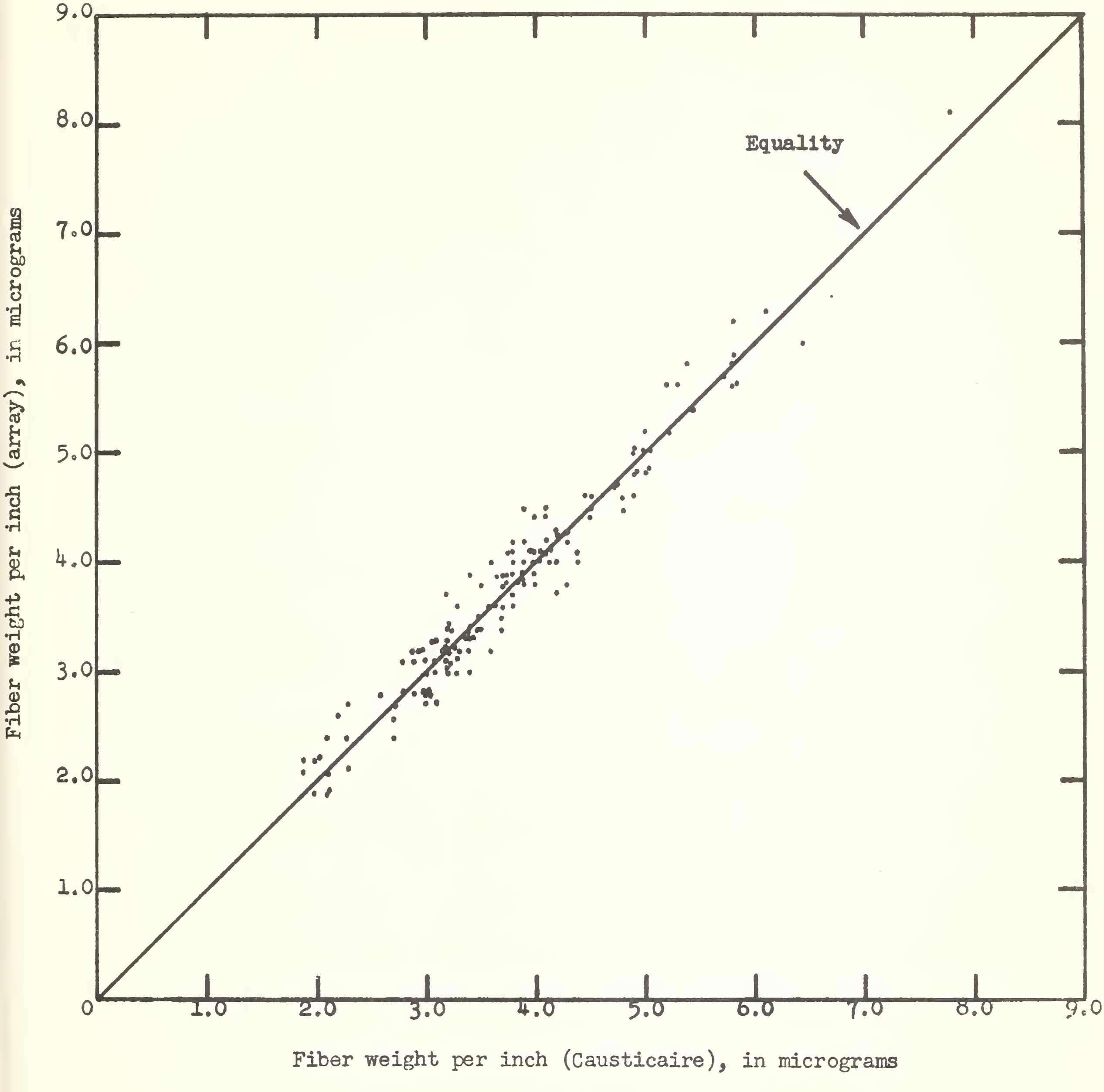

Figure 2.--Scatter diagram illustrating the relationship between paired values of fiber fineness (weight per inch) for 142 selected cottons, as determined by the Causticaire and array methods.

PROCEDURE OF TESTING BY THE CAUSTICAIRE METHOD

The Causticaire procedure for evaluating samples of cotton on the basis of fiber fineness and maturity is as follows:

1. Condition and blend a 7- to 10-gram laboratory sample on a mechanical cotton fiber blender, such as the one developed and described by Gaus and Larrison (9).

2. After calibrating the Micronaire instrument, weigh two 50-grain specimens and make standard Micronaire tests using Causticaire scale (one reading on each specimen).

3. Treat the two specimens plus residue from blended sample in a solution of sodium hydroxide (40 Tw) with a 1-1/2-percent wetting agent added. Be sure the sample is completely saturated.

4. Wash thoroughly in tap water.

5. Dry samples at a temperature not to exceed 220°F.

6. Condition and blend treated sample on mechanical fiber blender to fluff the cotton.

7. Weigh two 50-grain specimens and make standard Micronaire tests on treated samples using the Causticaire scale.

8. Calculate maturity index and fiber weight per inch, as follows:

CAUSTICAIRE MATURITY (index) =

$$\frac{\text{Average Causticaire reading (untreated)} \times 100}{\text{Average Causticaire reading (treated)}}$$

CAUSTICAIRE FINENESS (micrograms per inch) =

$$+1.185 + 0.00075\,(T^2) - 0.020\,(MI)$$

where, T = average of readings on treated specimen
MI = maturity index

The maturity index formula shown above is the same as that published by Burley and Bartmess (5) but the fineness formula (weight per inch) listed above is different from the previous one.

Effect of using varying concentrations of sodium hydroxide solution.

All preliminary work done on the Causticaire method has involved the use of a 40 (Tw) solution of sodium hydroxide. A test was made, therefore, to determine the effect, if any, on the measures obtained when varying the

concentration of the sodium hydroxide solution, and the extent to which the concentration of that chemical reagent must be controlled in order to give comparable results.

Three cottons, designated A, B, and C, were selected and tested according to the Causticaire method by using various concentrations of the sodium hydroxide solution. Each of the 3 cottons was tested in 3 replications with each of 4 different concentrations of sodium hydroxide, as follows: 34, 40, 46, and 52 (Tw). The average results obtained for the three replications of each cotton are shown in the following tabulation:

Concentration of sodium hydroxide solution (Tw)	Average maturity index for cottons			Average fineness (ug./in.) for cottons		
	(A)	(B)	(C)	(A)	(B)	(C)
34	86	83	72	5.4	4.4	3.0
40	86	80	70	5.5	4.6	3.1
46	86	82	72	5.5	4.5	3.0
52	86	82	71	5.4	4.5	3.0
Average	86.0	81.8	71.2	5.45	4.50	3.02

The results shown above indicate that equally reliable results were furnished by the Causticaire method at any concentration of sodium hydroxide solution used in this test. It is recommended, however, that the concentration of the chemical reagent be kept between 36 and 50 (Tw).

Effect of the time element involved in treatment of test specimens. In all the preliminary work performed with the Causticaire method, the time element was never considered as such, except to see that the samples were completely saturated with reagent. A test was made, therefore, to determine the effect, if any, on the values obtained when varying the amount of time a sample remained in the solution, and whether the time factor must be controlled in order to yield comparable results.

One cotton was selected and five specimens were prepared for this special test of the Causticaire method. All five specimens were completely saturated and each was allowed to remain in the solution of sodium hydroxide for different periods of time, as follows: 5, 10, 15, 20, and 25 minutes. The results obtained are shown in the following tabulation:

Time of sample in solution Minutes	Fiber Maturity Index	Causticaire weight per inch Micrograms
5	84	5.2
10	84	5.4
15	83	5.3
20	84	5.2
25	84	5.2
Average	83.8	5.26

The results indicate that the length of time the specimen remained in the solution of sodium hydroxide, after being completely saturated, had no detectable effect on determinations by the Causticaire method.

ACCESSARY EQUIPMENT FOR USE IN THE CAUSTICAIRE PROCEDURE

Several pieces of equipment are necessary in order to use the Causticaire method for the evaluation of cotton-fiber fineness and maturity. The minimum essential equipment is as follows:

1. A Micronaire instrument equipped with a Causticaire scale.
2. A mechanical cotton-fiber blender for preparation of specimens.
3. Equipment for drying the specimens.
4. A container for the sodium hydroxide solution and rubber gloves for use when treating the specimens.
5. Orlon marquisette bags for sample identification during the treatment, washing, and drying processes.
6. Running tap water for washing the specimens after treatment.

Special equipment for treating, washing, and damp drying the specimens automatically is now in process of development. This equipment is similar in principle to an automatic washer and has a storage tank for saving the caustic solution for reuse. Such equipment, if proved successful, will offer advantages to the Causticaire method of testing, as follows:

1. Speed up the treating, washing, and damp-drying processes.
2. Eliminate the need of an operator during the treating, washing, and damp-drying processes.
3. Reduce the hazard of an operator's coming into contact with the caustic solution.

SAMPLES, TESTS, AND DATA

The regular fiber, spinning, and yarn tests were made in the laboratories of the Department of Agriculture at Clemson, S. C. and at College Station, Tex. Tests for Causticaire maturity and fineness as well as for Arealometer fineness and maturity, however, were made at its cotton fiber laboratory in Washington.

Cottons. Data representing seven series of cottons were used in the various correlation analyses covered in this report, as follows:

1. A group of 142 cottons, selected to represent a wide range and uniform distribution with respect to fiber fineness and maturity, served as the basis for the development of the new Causticaire scale for evaluating both fiber fineness and maturity. Data representing this series of cottons also served as the basis for calibrating Causticaire fiber fineness measurements in terms of array fineness (weight per inch). This series of cottons included American upland, American Egyptian, Egyptian, Sea Island, triple hybrid, and Asiatic types.

2. A group of 72 cottons selected to cover a wide range and general distribution of fiber fineness and maturity was used in the correlation analyses for the evaluation of the relationship between Causticaire maturity index and percentage of mature fibers. This group of cotton included 53 American upland, 4 American Egyptian, 8 Egyptian, 5 Sea Island, and 2 hybrid types.

3. A group of 71 cottons, the same as that under item (2) except for the omission of one extreme American upland cotton, was included in the correlation analyses for the evaluation of the relationship between the other pairs of alternative fineness and maturity measures considered. The single upland cotton referred to above was omitted because it possessed such extremely low weight per inch and high percentage of immature fibers that it was found to be beyond the practical range of measurement with the Arealometer.

4. A group of 52 American upland cottons selected to cover a wide range and general distribution with respect to fiber fineness and maturity was used in the correlation analyses for evaluating the comparative significance of the alternative measures of fiber maturity (Causticaire maturity index, Arealometer immaturity ratio, and percentage of mature fibers by the standard method) in terms of

three dependent variables; namely, number of neps per 100 square inches of card web, appearance of 36s yarn, and skein strength of 36s yarn.

5. A group of 319 cottons grown by selected cotton improvement groups, crop year of 1951, was used in correlation analyses for evaluating the relative significance of Causticaire fineness and maturity versus Micronaire fineness and percentage of mature fibers (standard maturity) in terms of five dependent variables; namely, number of neps per 100 square inches of card web, appearance of 22s yarn, collective appearance of all yarn sizes spun, skein strength of 22s yarn, and count-strength product of all yarn sizes spun.

6. A group of 309 cottons grown by selected cotton improvement groups, crop year of 1952, was used in parallel analyses to those referred to above for the 1951 samples.

7. A group of 50 cottons selected out of the 1951 series, on the basis of graduated values for fiber fineness (weight per inch) and maturity, was used in correlation analyses of a supplementary nature. Twenty-five cottons were selected to represent equal steps of 0.1 micrograms (weight per inch) over the range of 2.7 micrograms to 5.6 micrograms, as determined by the Causticaire method. And, 25 additional cottons were chosen to represent equal steps of 1 point maturity index over the range of 64 to 85 maturity index, as evaluated by the Causticaire method. These two groups of selected cottons were combined into one series and used in correlation analyses for evaluating Causticaire fineness and maturity versus Micronaire fineness and percentage of mature fibers (standard method) in terms of 3 dependent variables; namely, number of neps per 100 square inches of card web, appearance of 22s yarn, and skein strength of 22s yarn.

<u>1951 and 1952 cottons</u>. Fiber, yarn-appearance, and yarn-strength data identified with 319 cottons from the 1951 crop and similar data associated with 309 cottons from the 1952 crop, as reported by the Department of Agriculture (21) and (23), respectively, served as the basis for the multiple and simple correlation analyses included in this study. No data representing Causticaire fiber fineness, Causticaire maturity, and count-strength product, however, were included for those cottons in the two reports cited. Such values for those three measures as used in these analyses, therefore, constitute unpublished data.

All cottons were of the American upland type and represented some leading varieties in commercial production grown by 107 selected cotton improvement groups across the United States Cotton Belt, crop of 1951, and by 103 selected cotton improvement groups, crop of 1952. The cottons were grown commercially within their general area of growth adaption and

they were ginned on commercial saw gins serving the respective cotton improvement groups.

Classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton-improvement area until 8 to 10 pounds of raw cotton had been accumulated. With two exceptions, each variety and location of growth were represented by 3 dates of harvesting, namely, early season, mid-season and late-season samples.

The original grade and staple length designations, which served as the basis for selecting and compositing the comparable lots of cotton for test purposes, were those assigned to the individual samples of raw cotton by cotton specialists of the Department. Classification of the samples was made in accordance with the Universal Standards for Grade and the official standards for staple length, as described for American upland cotton in "The Classification of Cotton" (20).

As a result of the method used for selecting the samples, the entire range of grades and staple lengths appearing in each cotton improvement area was not represented by the tested cottons.

Processing of 1951 and 1952 cottons. The cottons were processed in the spinning laboratories, according to the general procedures and conditions outlined in Cotton Testing Service (22) and as described further in reports (21) and (23). All the cottons used in this study were processed through the picker and card by the same standard procedure, and with the same settings and speeds. The samples grown by selected cotton improvement groups were carded at different rates of production and spun into two sizes of yarn, as referred to further in the chapter entitled "Discussion."

All yarns were processed from long-draft rovings by long-draft spinning equipment, represented a warp-type of construction, and possessed a semihard twist. The twist multipliers used varied with the upper half mean length of the cottons, the one selected for each being that which gave approximately the maximum yarn strength for an average or typical cotton of the particular upper half mean length. The twist multiplier used in each case, therefore, was not selected to compensate for the influence of other fiber properties involved but represented an empirical selection.

Independent variables. Measurements of five fiber properties of raw cotton were used as independent variables in the multiple correlation analyses for the 52 selected samples included in this study, as follows:

1. Upper half mean length, in inches, as determined by the fibrograph method.

2. Length uniformity ratio, in percent, as determined by the fibrograph.

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3. Fiber strength, in terms of 1,000 pounds per square inch, as determined by the Pressley tester.

4. Fiber fineness, in micrograms per inch, as evaluated by the array method.

5. Percentage of mature fibers, as classified and counted on the basis of 2-to-1 lumen to wall ratio, after they had been permitted to swell in an 18-percent sodium hydroxide solution.

With the 1951 and 1952 samples, six elements of raw-cotton quality were included as independent variables in the analyses. The same 5 fiber properties listed above were used, except that Micronaire fineness (weight per inch) was used instead of array fineness. Grade of cotton expressed as an index was included as the sixth independent variable. Yarn size, expressed in terms of the generally used or so-called English yarn numbers for cotton, was used as the seventh independent variable in the correlation analyses, when count-strength product or collective appearance of various yarn sizes was used as the dependent variable.

Alternative measures of fiber fineness were used as independent variables in various analyses of this study, as follows:

1. Causticaire fiber fineness, in micrograms per inch

2. Arealometer fiber fineness, in micrograms per inch

3. Micronaire fiber fineness, in micrograms per inch

4. Array fiber fineness, in micrograms per inch

Alternative measures of fiber maturity were used as independent variables in certain analyses, as follows:

1. Causticaire maturity index

2. Arealometer immaturity ratio

3. Percentage of mature fibers (standard method)

The standard fiber tests which furnished the data used in these analyses were those described in Cotton Testing Service (22) and in the ASTM publication (4). Details of the Micronaire fineness test are covered more fully in the Sheffield Instruction Manual (14). A complete description of the Arealometer method for evaluating fiber fineness and maturity in cotton samples is given in the Spinlab Instruction Manual (16).

A conventional number of tests per sample was made for all fiber tests, according to the recommended procedures, except two, namely, Arealometer fineness and maturity. With the Arealometer, an average of data from two tests per sample is recommended by the Spinlab Instruction Manual (16), if the results from the duplicate tests are in close agree-

ment; if they are not in close agreement, an average of data obtained from three tests is recommended for the exceptional samples.

In the Arealometer tests which furnished data used in the analyses covered by this report, four tests per sample were made in all cases and an average of the data from four tests was used to represent each sample. This modification in procedure was made in an effort to obtain more accurate and representative averages for the respective samples than would have been possible on the basis of either two or three tests per sample.

All fiber tests were made under controlled atmospheric conditions with a temperature of 70°F. ± 2° and a relative humidity of 65 percent ±2 percent, according to ASTM specifications (4).

Dependent variables. For the 52 selected cottons previously referred to, dependent variables were used in analyses, as follows:

1. Neps, number per 100 square inches of card web.

2. Appearance of 36s carded yarn, index.

3. Skein strength of 36s carded yarn, pounds.

For the 1951 and 1952 cottons, dependent variables were included as follows:

1. Neps, number per 100 square inches of card web.

2. Appearance of 22s carded yarn, index.

3. Collective Appearance of all yarn sizes, index.
   (14s and 22s for 39 shortest cottons, 1951)
   (14s and 22s for 33 shortest cottons, 1952)
   (22s and 50s for 280 longer cottons, 1951)
   (22s and 50s for 276 longer cottons, 1952)

4. Skein strength of 22s carded yarn, pounds.

5. Count-strength product of all yarn sizes, csp units.
   (Yarn sizes were the same as for collective appearance.)

Conventional skein-strength tests, yarn-appearance evaluations, and nep count of card web were made according to the generally adopted procedures and conditions described in cotton testing service (22) and ASTM publication (4).

All yarn-strength tests were made under the same controlled atmospheric conditions, as specified by ASTM for fiber and yarn testing, namely a temperature of 70°F. ± 2° and a relative humidity of 65 percent ±2 percent.

STATISTICAL ANALYSES

A total of 159 correlation analyses was made in connection with this study: 67 multiple analyses and 92 simple analyses. The results from only 43 correlation analyses, however, are presented in this report as follows: 35 multiple and 8 simple.

In the case of the correlation analyses for the 52 selected cottons, alternative measures for fiber maturity were substituted separately, that is, one at a time. With the series of analyses for the 1951 and 1952 cottons, however, the alternative measures were substituted in pairs; for example, Micronaire fineness and percentage of mature fibers (standard method) versus Causticaire fineness and Causticaire maturity. This procedure seemed logical because of the fact that interest lies principally in the Causticaire method from the standpoint of evaluating both fiber fineness and maturity simultaneously, as the two Causticaire values for a sample are uniquely oriented with respect to each other, rather than of determining either fiber fineness or maturity by the Causticaire method and the other by the standard maturity of Micronaire test.

The independent and dependent variables used in all the analyses covered by this report, including four alternative measures of fiber fineness (weight per inch) and three alternative measures of fiber maturity were listed in the previous chapter entitled "Samples, Tests, and Data."

Simple correlation analyses were made for determining the degree of relationship occurring between all possible pairs of independent and dependent variables for the 1951 and 1952 series of cottons, that is, by correlating only one fiber measure at a time with a dependent variable and disregarding all interrelationships between the fiber properties. Those results, however, have not been included in this report. They served, nevertheless, as background material for making certain observations and comparisons in the preparation of this report.

Correlation analyses were made for determining the degree of relationship existing between each pair of alternative measures of fiber fineness and of fiber maturity for a given series of cottons. All such parallel analyses, however, were not identified with the same group of cottons.

Values for the means, standard deviations, and ranges of data for the respective independent and dependent variables included in the correlation analyses covered in this report are summarized in table 1 for the 52 selected cottons, in table 2 for the 1951 series of cottons, and in table 3 for the 1952 cottons. (See Appendix 2/.)

Tabulations of the comparative values for the means, standard deviations, and ranges of data representing all possible pairs of alternative measures of fiber fineness (weight per inch), as used in the correlation analyses, may be found in the next chapter entitled "Relationship between Alternative Measures of Fiber Fineness." Tabulations of similar

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2/ All tables are grouped in the Appendix at the end of this report and hereinafter they will be referred to only by table number.

values for all possible pairs of alternative measures of fiber maturity are given in the chapter entitled "Relationship between Alternative Measures of Fiber Maturity."

All statistical values reported herein were obtained from linear correlation analyses. The usual correction factor was applied to the respective statistical values obtained from all correlation analyses.

Beta coefficients were used to evaluate the relative net importance of the respective fiber measures to the various dependent variables.

RELATIONSHIP BETWEEN ALTERNATIVE MEASURES OF FIBER FINENESS

Causticaire and array fineness. Figure 2 illustrates the relationship between Causticaire and array fiber fineness values (weight per inch) for 142 cottons selected to represent a wide range and uniform distribution with respect to fiber fineness and maturity. That series of cottons included American upland, American Egyptian, Egyptian, Sea Island, triple hybrid, and Asiatic types.

A correlation analysis of the Causticaire and array fineness values (weight per inch) for that series of mixed growths of cotton, representing different botanical species, gave a correlation coefficient of +0.976.

The distribution of the fiber-fineness data entering into the analysis for that group of 142 cottons, as expressed in micrograms per inch, is indicated by the following tabulation:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	3.79	± 1.01	1.9	7.8	5.9
(2) Array	3.81	± 1.04	1.8	8.1	6.3
Difference (1)-(2)	-.02	- .03	+.1	-.3	-.4

Arealometer and array fineness. Figure 3 shows the values of Arealometer fiber fineness plotted against array fiber fineness for 71 samples of cotton, as follows: 52 American upland, 4 American Egyptian, 8 Egyptian, 5 Sea Island, and 2 hybrid types. These samples were selected to represent a wide range and uniform distribution with respect to fiber fineness.

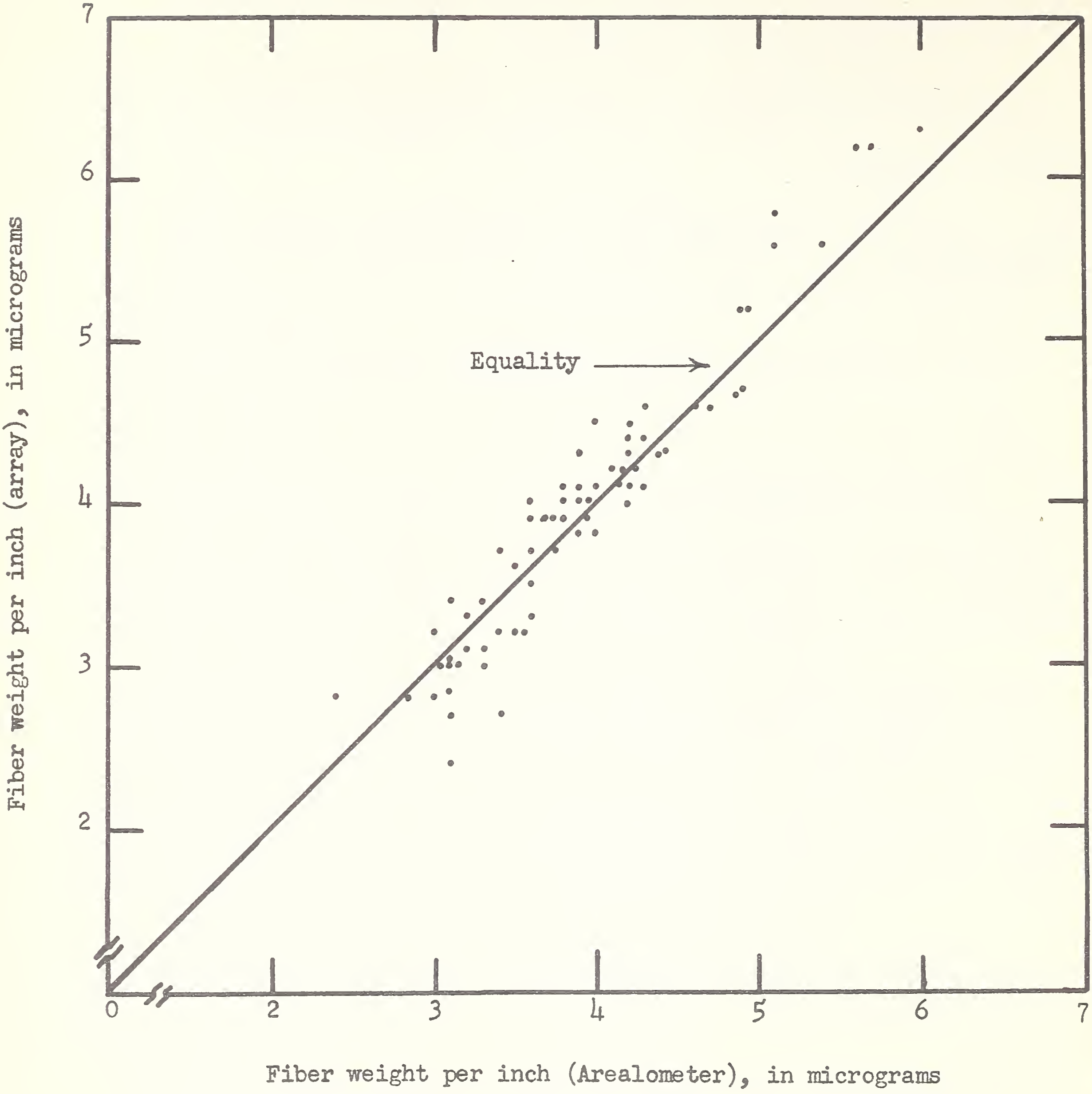

Figure 3.--Scatter diagram illustrating the relationship between paired values of Arealometer and array fiber fineness (weight per inch) for 71 selected cottons.

A correlation analysis of the Arealometer and array fineness values for the series of mixed growths of cotton, as referred to before, showed a correlation coefficient of +0.959.

The fiber fineness data that were used in the analysis for that group of 71 selected cottons are indicated by the values of micrograms per inch shown below:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Arealometer	3.88	± .70	2.4	6.0	3.6
(2) Array	3.93	± .85	2.4	6.3	3.9
Difference (1)-(2)	-.05	- .15	.0	-.3	-.3

Causticaire and Arealometer fineness. Figure 4 is a scatter diagram of values for this pair of alternative measures of fiber fineness, representing the same 71 selected cottons referred to above.

The correlation coefficient obtained for Causticaire and Arealometer fineness (weight per inch) in this instance was +0.952.

The fiber-fineness data used in this analysis, as identified with the alternative measures under consideration, are indicated by the values for micrograms per inch as follows:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	3.89	± .76	2.7	6.3	3.6
(2) Arealometer	3.88	± .70	2.4	6.0	3.6
Difference (1)-(2)	+.01	+ .06	+.3	+.3	0

Causticaire and Micronaire fineness. For the 319 American upland cottons, crop of 1951, a correlation coefficient of +0.885 was obtained between the measures of Causticaire and Micronaire fineness (weight per inch).

In figure 5, there appears a scatter diagram of the values of Causticaire fiber fineness representing that series of upland cottons plotted against the corresponding values for Micronaire fineness. A considerable concentration of observations may be noted around the respective mean values.

The basic fiber-fineness data used in the analysis for that

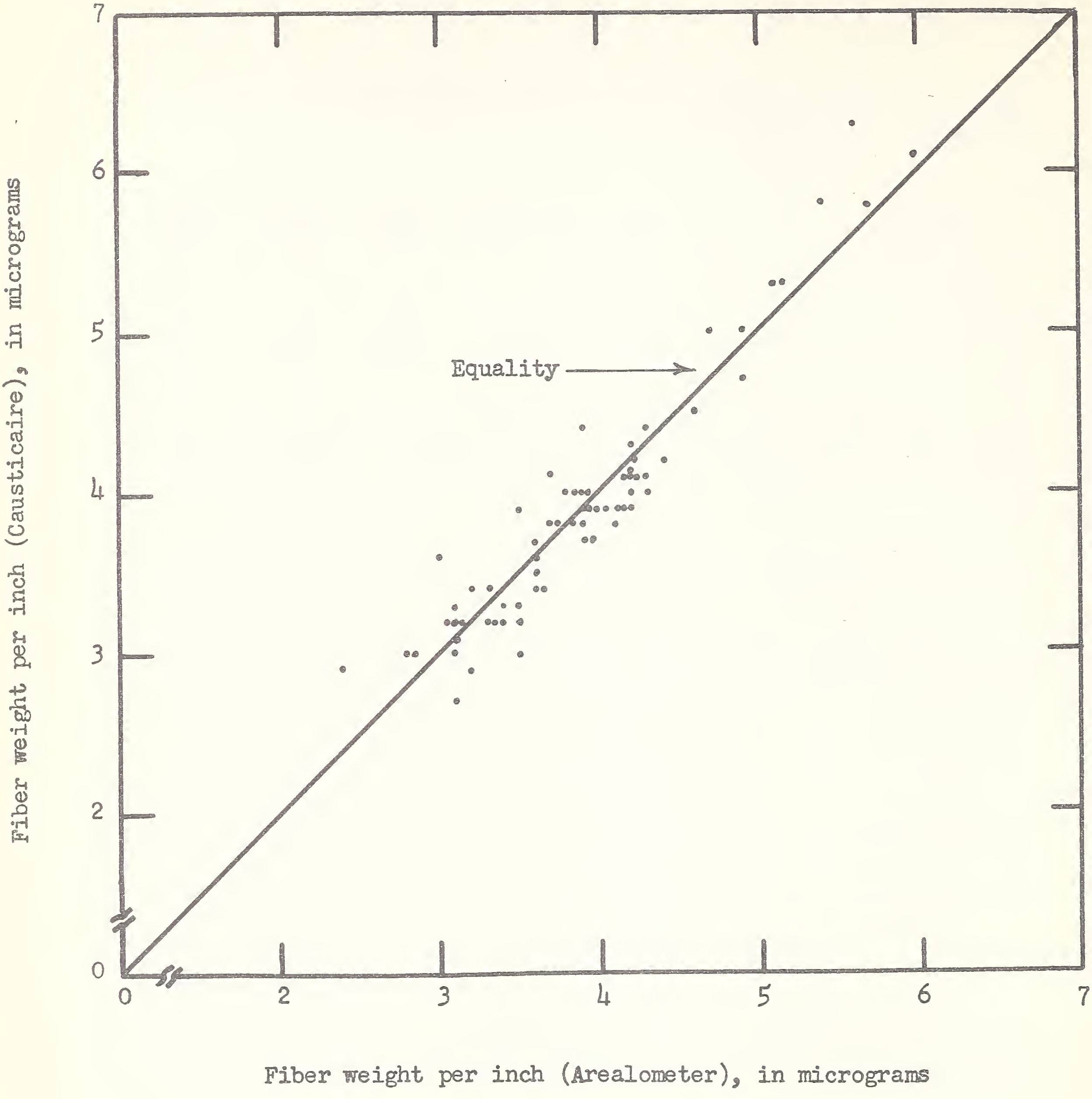

Figure 4.--Scatter diagram illustrating the relationship between paired values of Causticaire and Arealometer fiber fineness (weight per inch) for 71 selected cottons.

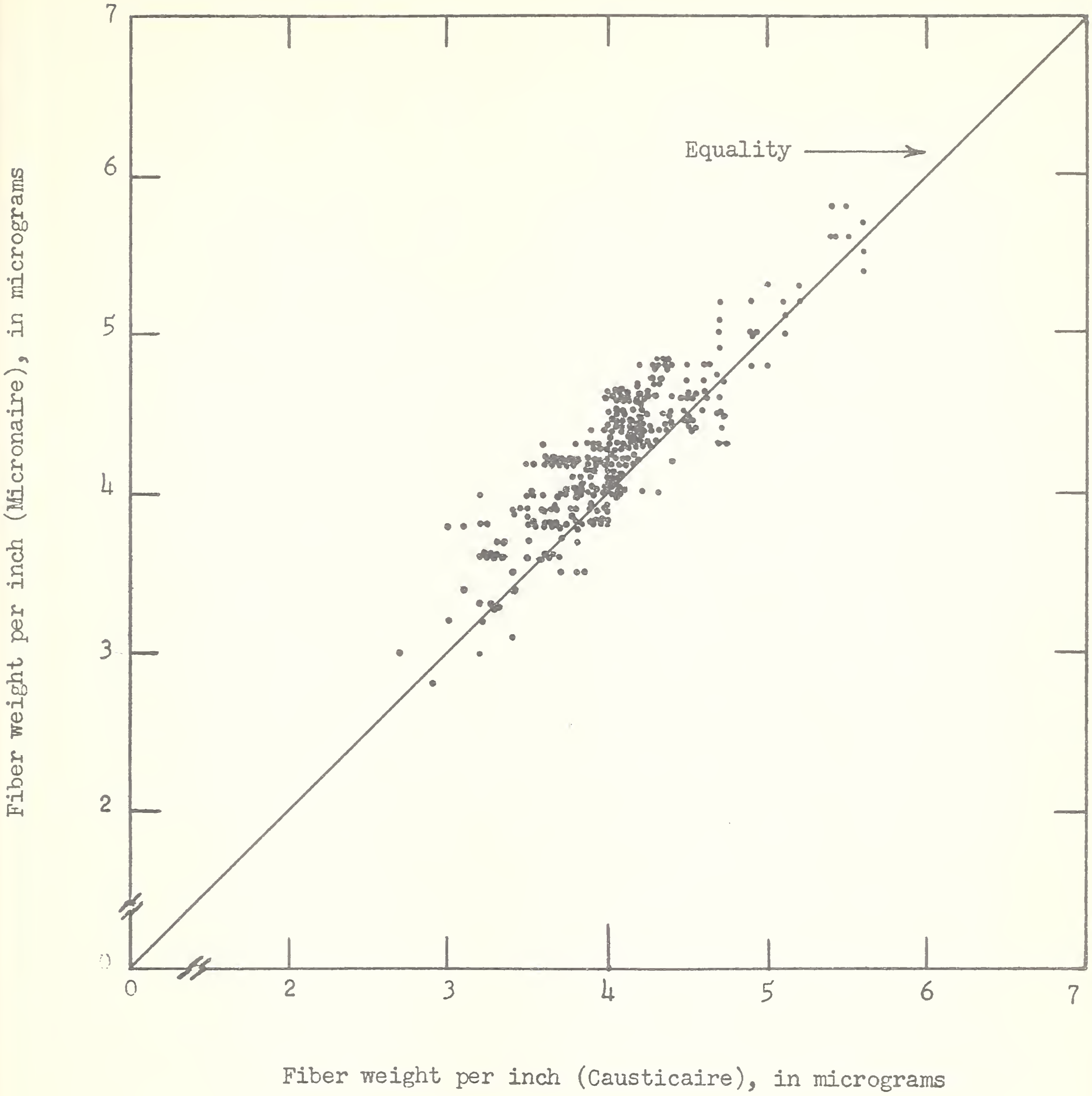

Figure 5.--Scatter diagram illustrating the relationship between paired values of Causticaire and Micronaire fiber fineness (weight per inch) for 319 cottons, crop year 1951.

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group of 319 upland cottons, expressed in terms of micrograms per inch, compared as follows:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	4.04	± .48	2.7	5.6	2.9
(2) Micronaire	4.25	± .46	2.8	5.8	3.0
Difference (1)-(2)	-.21	+ .02	-.1	-.2	-.1

General considerations. From the foregoing tabulations, it would appear that the alternative measures of fiber fineness agreed reasonably close in terms of mean values and standard deviations for the different series of cottons. Somewhat larger disparities, however, occurred in the case of the respective minimum and maximum values previously reported in the tabulations for the alternative measures. But, even such comparative values for the extremes of fiber weight per inch do not, in fact, reveal the full nature and extent of disparities actually occurring in the intermediate values of the alternative measures throughout any comprehensive series of cottons.

For example, on the basis of the findings for the 71 selected samples of cottons, the Causticaire, Arealometer, and array measures of fiber fineness did not show their respective maximum values to be identified with the same sample; nor did they reveal their respective minimum values to be associated with the same sample. Rather, the respective extremes of fiber fineness varied among the different samples, the results depending on which one of the three tests—Causticaire, Arealometer, or Array method—was used to evaluate fiber fineness.

The fluctuations observed for the comparative minimum and maximum values of fiber fineness (weight per inch), as identified with the three alternative measures representing 71 cottons selected to cover a wide range of micrograms per inch, suggest that such variations and disparities also existed in more or less degree for the intermediate values representing the different methods of test. That they did occur is illustrated by the graphic chart shown in figure 6. Obviously, it is fluctuations of such nature and extent that go to explain the measurable differences found in the comparative significance of the alternative measures of fiber fineness toward nep count of card web, yarn appearance, and yarn strength, as covered in later chapters of this report.

Although all the correlation analyses referred to in this chapter were not identified with the same group of cottons and all the correlation values obtained for the different pairs of alternative measures of fiber fineness (weight per inch) are not precisely comparable, a summary tabulation of such values is of general interest. (See page 24.)

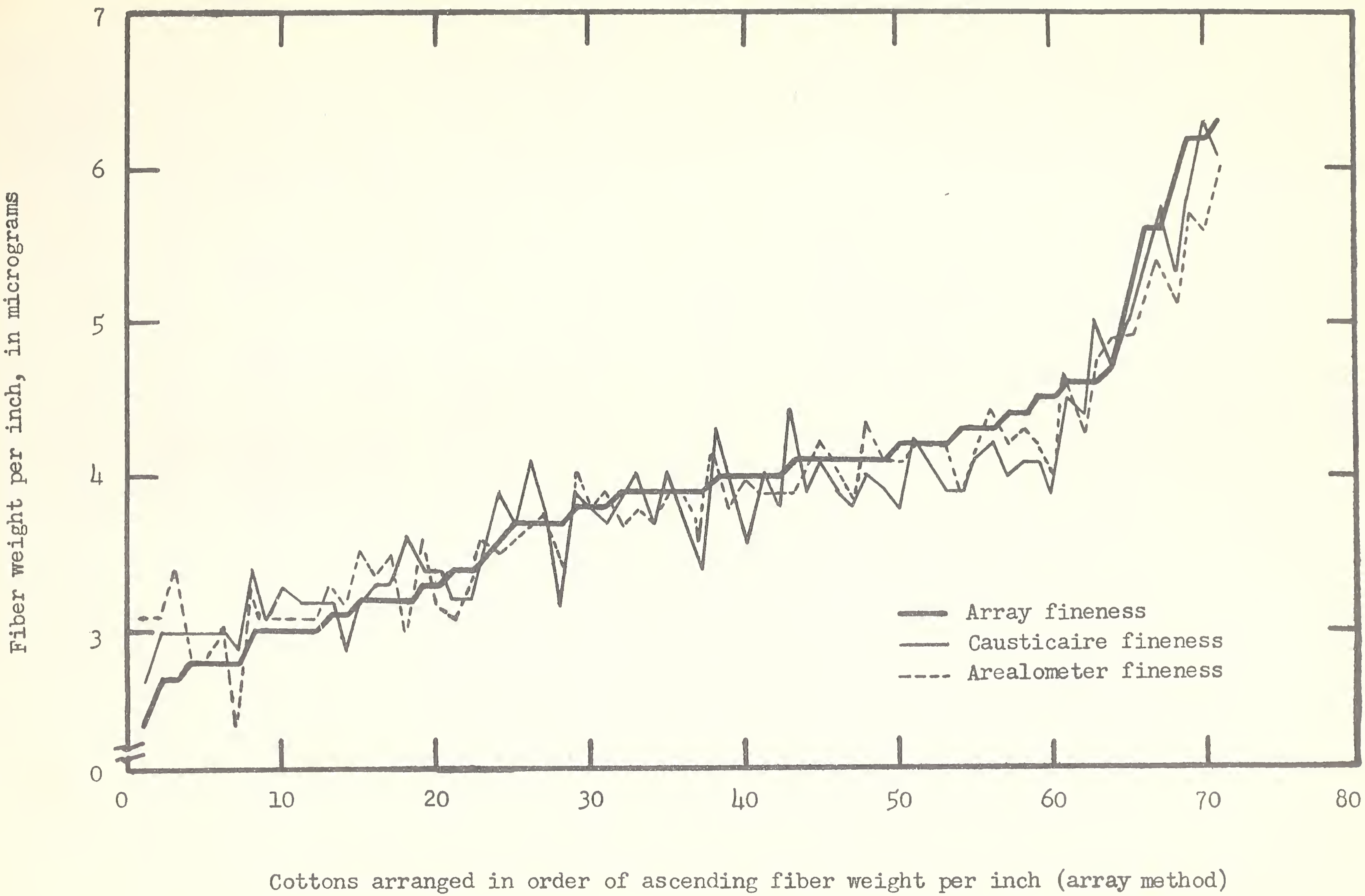

Figure 6.--Chart illustrating the relationship between the values representing three alternative measures of fiber fineness (weight per inch) for 71 selected cottons.

Alternative measures	Samples Number	(R)
Causticaire and array fineness	142	+0.976
Arealometer and array fineness	71	+ .959
Causticaire and Arealometer fineness	71	+ .952
Causticaire and Micronaire fineness	319	+ .885

In the light of the foregoing values, it is evident that, with the exception of Causticaire and Micronaire fineness associated with the 319 cottons of the 1951 series, a comparatively high degree of correlation occurred between the various pairs of alternative measures of fiber fineness. The somewhat smaller coefficient of correlation obtained with the largest series of cottons is explained by the fact that the range of fineness was more restricted in this case than in the other series of cottons studied, and that there was a considerably greater concentration of observations around the mean values for the two measures of fiber fineness. However, had the range of fiber fineness been wider in the series of 319 cottons and had the observations been distributed more equally throughout the entire range of fiber fineness, there is reason to believe that the coefficient of correlation for Causticaire and Micronaire fineness would have been larger than that reported and on a par with the values shown in the other cases.

RELATIONSHIP BETWEEN ALTERNATIVE MEASURES OF FIBER MATURITY

Causticaire and standard maturity. A scatter diagram of the values for percentage of mature fibers, representing 319 American upland cottons from the 1951 crop, as determined by the standard maturity test, plotted against the corresponding values for Causticaire maturity index is shown in figure 7. A considerable concentration of observations may be noted around the respective mean values. The comparative values for the two maturity measures, representing this series of cottons, are indicated by the following tabulation:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	78.8	± 3.15	62	86	24
(2) Standard	82.4	± 4.54	64	92	28
Difference (1)-(2)	-3.6	- 1.39	-2	-6	-4

A correlation coefficient of +0.752 was obtained from the analysis of that series of cottons.

The degree of correlation found to exist between percentage of mature fibers and Causticaire maturity index in the case of the large series of American upland cottons referred to above did not prove to be as large as that which Burley and Bartmess reported in their preliminary

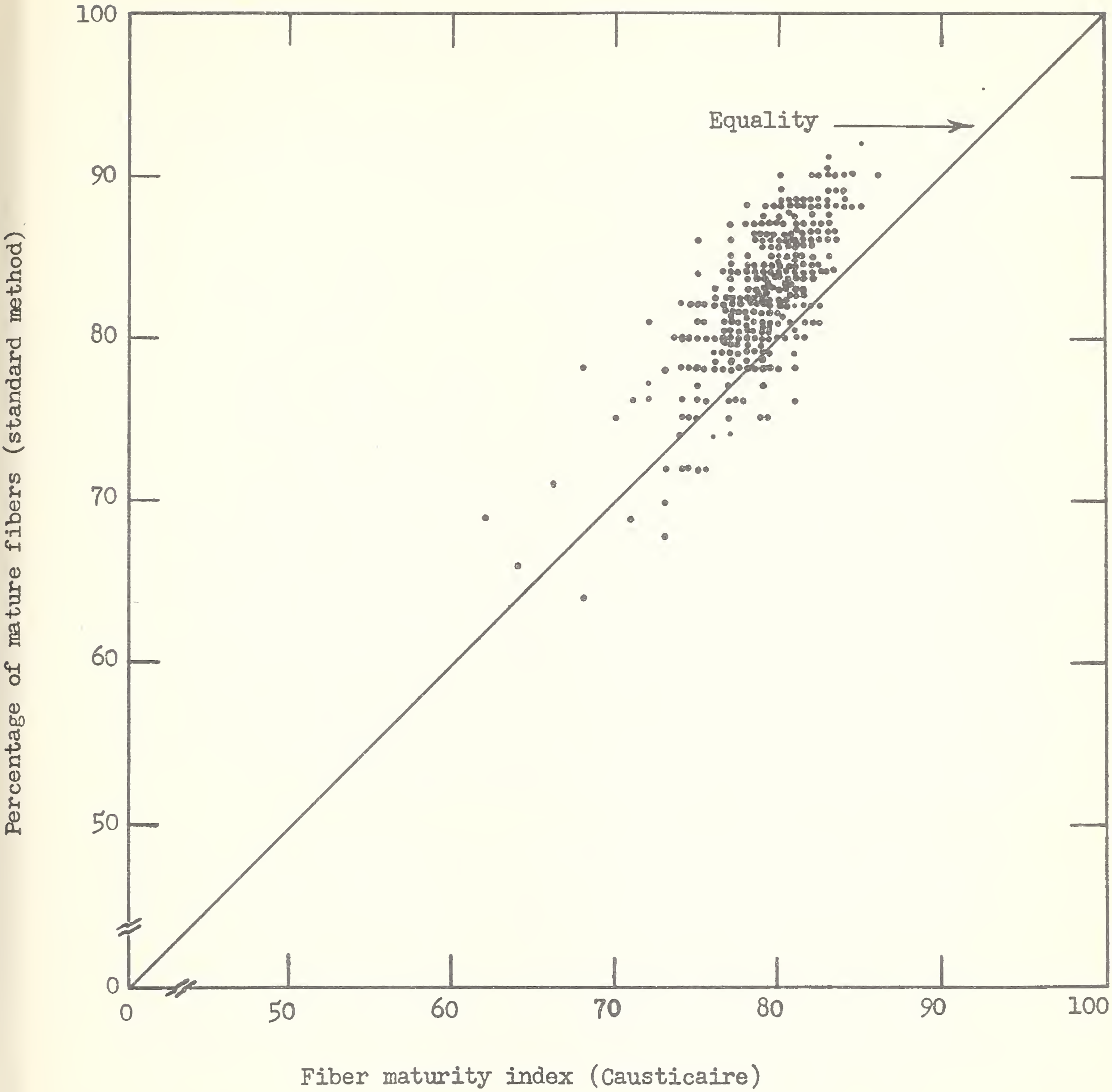

Figure 7.—Scatter diagram illustrating the relationship between paired values of Causticaire and standard fiber maturity for 319 cottons, crop of 1951.

publication (5) for 72 selected cottons: 53 American upland, 5 Sea Island, 8 Egyptian, 4 American Egyptian, and 2 hybrid types. They obtained a correlation coefficient of +0.895 for the relationship between percentage of mature fibers (standard method) and Causticaire maturity index for that series of mixed growths of cotton.

Figure 8 shows comparative values for the two maturity measures, representing the series of 72 selected cottons referred to above. The comparative values also are indicated as follows:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	77.7	± 7.53	33	87	54
(2) Standard	83.0	± 8.60	36	94	58
Difference (1)-(2)	-5.3	- 1.07	-3	-7	-4

The disparity in the two sets of correlation values for percentage of mature fibers and Causticaire maturity index is not surprising. Those samples studied by Burley and Bartmess (5), which gave a considerably higher correlation value were especially selected to represent a wide range and uniform distribution of fiber maturity, not only within the upland group of cottons that made up the bulk of the series, but also in the growth that included a sizable number of American Egyptian, Egyptian, and Sea Island cottons. On the other hand, the 319 upland cottons, included in the present study represented a more restricted range of fiber fineness and maturity, and possessed a higher concentration of samples around the mean values for those fiber properties.

All things considered, therefore, the agreement of the Causticaire maturity index with the standard fiber maturity expressed as percentage of mature fibers is reasonably good in both series of cottons. As pointed out previously, however, the new Causticaire measure of fiber maturity is not proposed as, nor necessarily expected to be, a method for obtaining perfect correlation with values from the standard maturity test. Thus, even if a smaller degree of correlation had been found to exist between the alternative measures of fiber maturity than that reported here, it would have been neither surprising nor disturbing.

Arealometer and standard maturity. Figure 9 shows maturity values obtained by the Arealometer and the standard methods for 71 selected samples of cotton. For the purpose of comparison, the values of imaturity ratio, as determined by the Arealometer method, were converted to percentage of mature fibers on the basis of the relationship reported in the Arealometer Instruction Manual (16). This series of cottons was the same as the 72 selected cottons previously considered, except for the omission of one

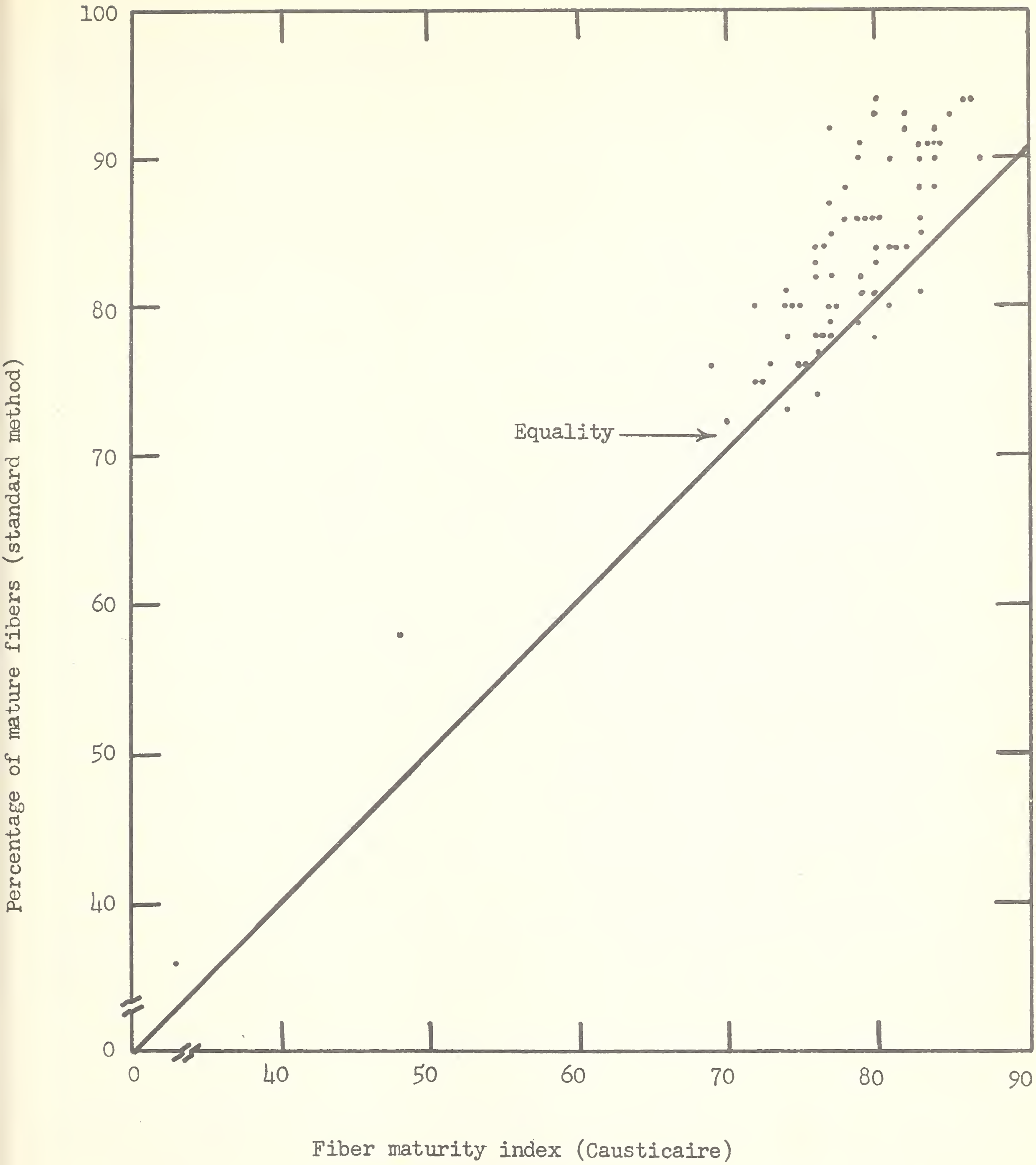

Figure 8.--Scatter diagram illustrating the relationship between paired values of Causticaire and standard fiber maturity for 72 selected cottons.

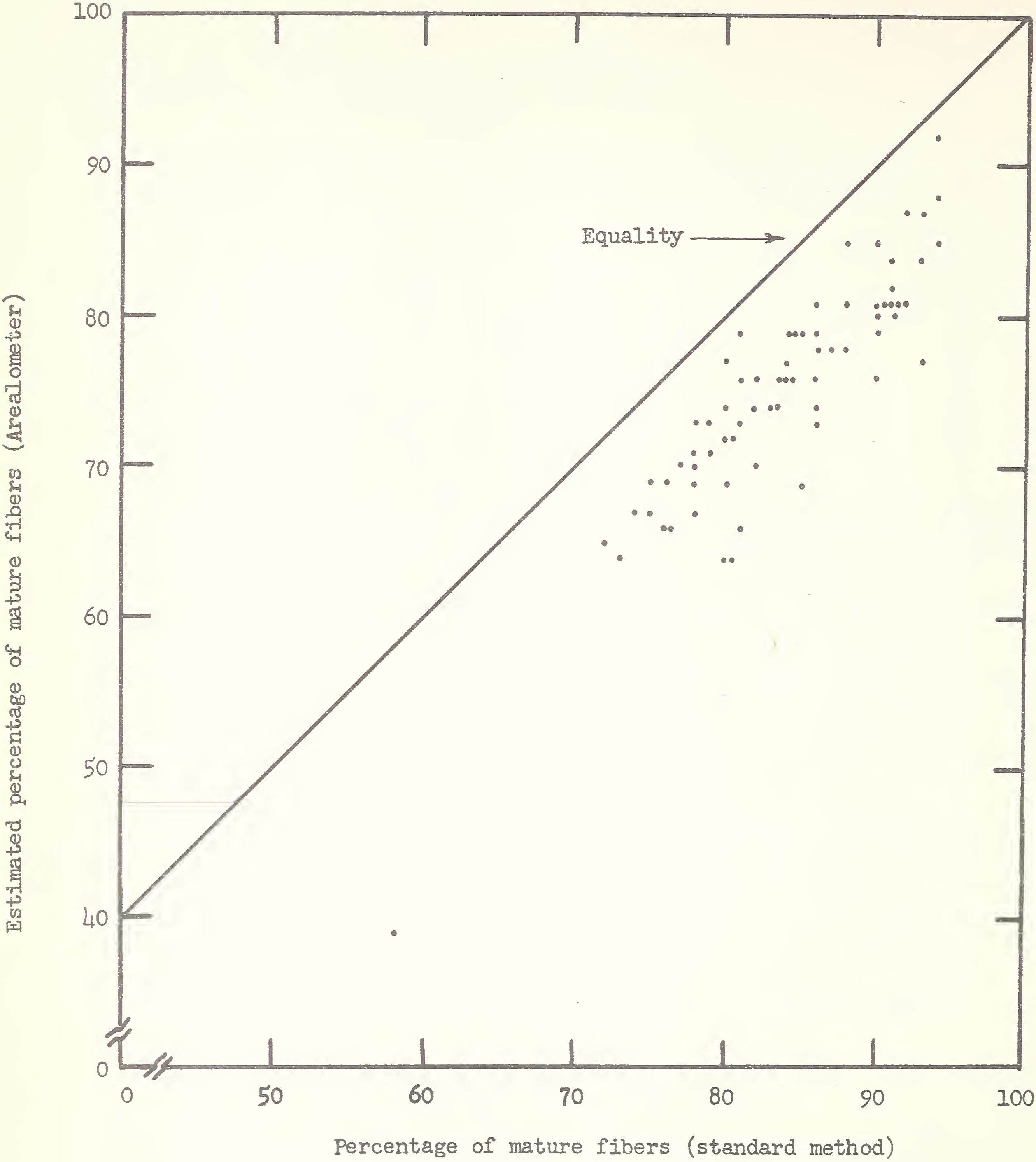

Figure 9.—Scatter diagram illustrating the relationship between paired values of Arealometer and standard fiber maturity for 71 selected cottons.

upland cotton which had a fiber weight per inch so small a percentage of immature fibers so large that it proved to be beyond the practical range of accurate measurement by the Arealometer.

The comparative values for the two maturity measures, representing that series of mixed growths of cotton, are, as follows:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Arealometer	75.1	± 7.71	39	92	53
(2) Standard	83.6	± 6.64	58	94	36
Difference (1)-(2)	-8.5	+ 1.07	-19	-2	+17

The degree of relationship occurring between the values of fiber maturity furnished by the Arealometer method and percentage of mature fibers (standard method), representing the series of cottons referred to above, was indicated by a correlation coefficient of +0.889.

Causticaire and Arealometer maturity. On the same 71 cottons, the relationship existing between the values of fiber maturity furnished by the Arealometer and those obtained by the Causticaire method was shown by a correlation coefficient of +0.881.

Figure 10 shows two sets of values representing the Causticaire and Arealometer measures of fiber maturity. For the purpose of comparison, the values of immaturity ratio, as determined by the Arealometer, were converted to percentage of mature fibers on the basis of the relationship reported in the Arealometer Manual (16).

The comparative values for the two maturity measures representing that series of mixed growths of cotton, are indicated by the tabulation below:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	78.3	±5.39	48	87	39
(2) Arealometer	75.1	±7.71	39	92	53
Difference (1)-(2)	+3.2	-2.32	+9	-5	-14

General considerations. On the basis of the foregoing data, it is evident that the values representing the alternative measures of fiber maturity were similar in certain particulars and rather consistently different in other respects. In general, as shown by figure 11, the levels in magnitude of values differed appreciably for the three different measures of fiber maturity. For the 71 selected cottons, representing a wide range and general distribution of fiber maturity,

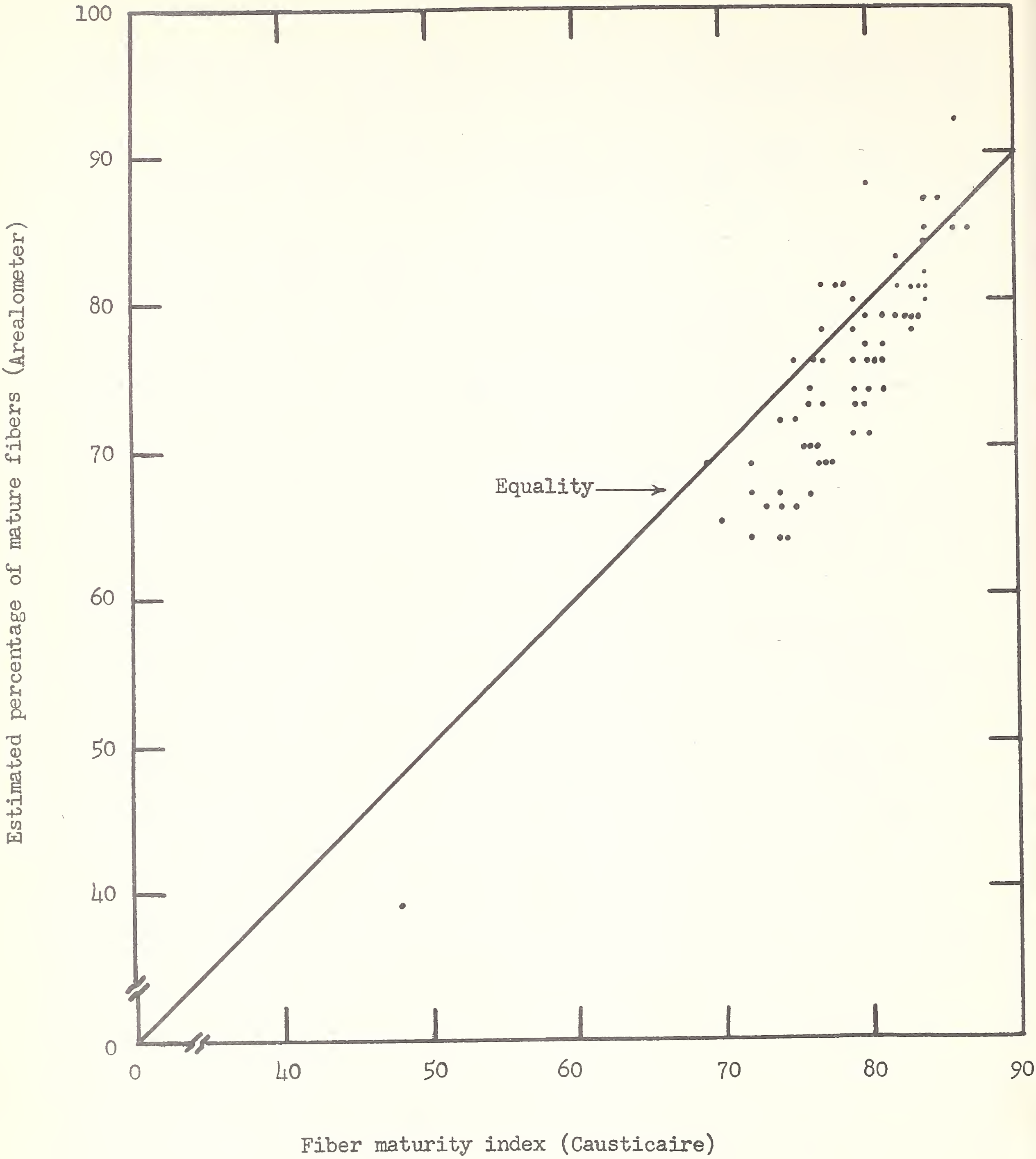

Figure 10.--Scatter diagram illustrating the relationship between paired values of Causticaire and Arealometer fiber maturity for 71 selected cottons.

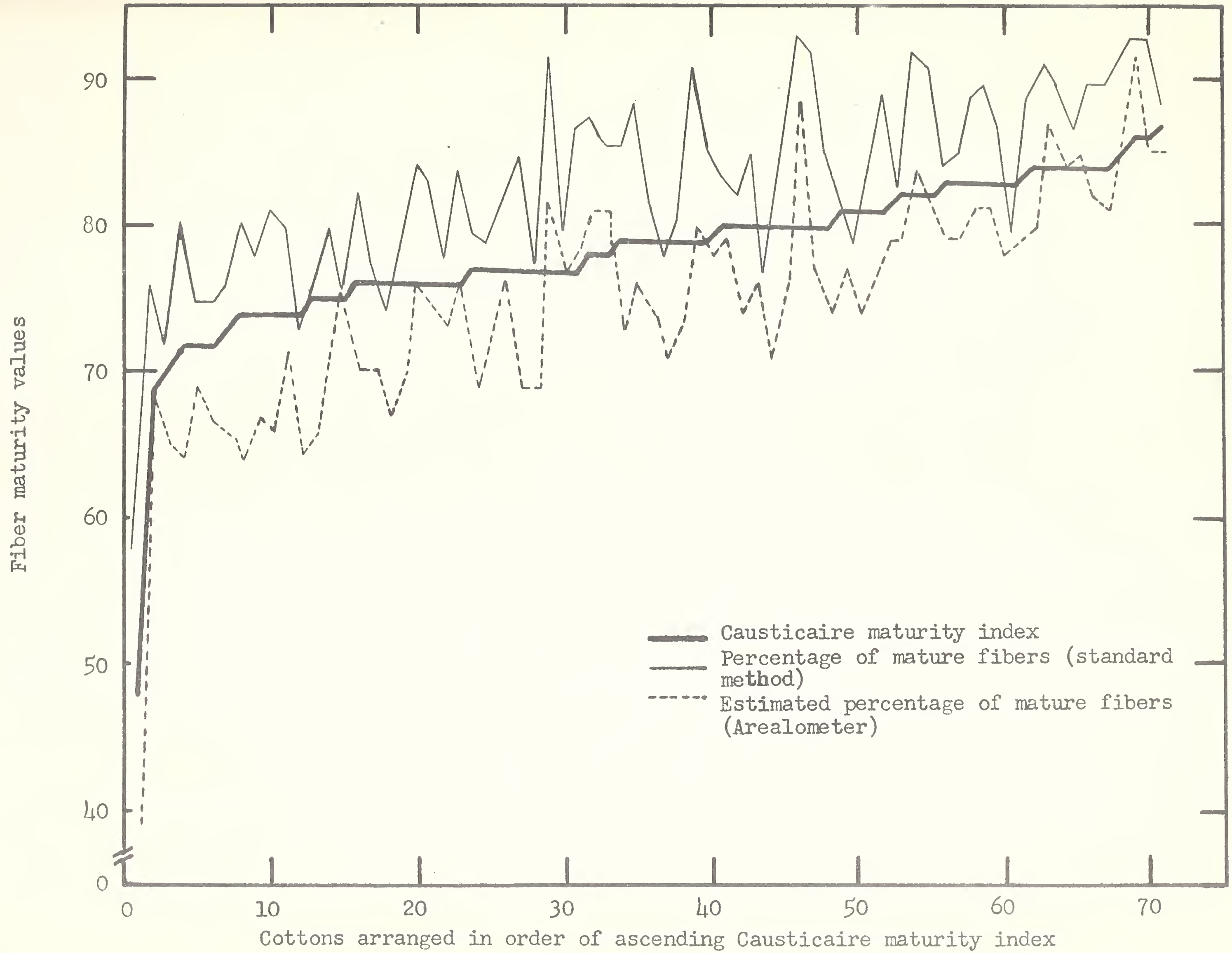

Figure 11.--Graphic chart illustrating the relationship between the values representing three alternative measures of fiber maturity for 71 selected cottons.

the standard method gave the highest mean value for percentage of mature fibers, namely, 83.6 percent. The mean Causticaire index for this series of cottons was 78.3 or 5.3 units lower than the mean value obtained by the standard method. And, the corresponding mean value for percentage of mature fibers as estimated from the immaturity ratio determined by the Arealometer, was 75.1 percent. Thus, the mean value for fiber maturity by the Arealometer was 3.2 units lower than that by the Causticaire method and 8.5 units below that by the standard maturity.

In figure 11, the corresponding values of the three maturity measures for the 71 selected cottons previously referred to have been plotted, the cottons being arranged in sequence of ascending order on the basis of values for Causticaire maturity index. The plotted points for each series of measurements have been connected by a line merely to assist the eye of the reader in following the comparisons.

To obtain the comparison desired in figure 11, the values of immaturity ratio furnished by the Arealometer method were converted into terms of percentage of mature fibers on the basis of the relationship reported in the published manual of instruction for operating the Arealometer (16). However, in the correlation analysis with nep count of card web, with yarn appearance, and with yarn strength, which will be considered later in this report, the values of immaturity ratio (Arealometer) were used directly.

Of outstanding interest in figure 11 is the striking similarity of the trend lines connecting the series of values by the standard method and those by the Arealometer method; in fact, they appear to be almost identical except for being on two rather distincly different levels. This is a remarkable achievement for two such radically different methods of test on a property that is as variable and difficult to evaluate as cotton-fiber maturity.

Another point of special interest in figure 11 is the fact that, when the series of values for Causticaire maturity index were plotted in ascending order for the 71 selected cottons, the parallel fluctuations in corresponding values of maturity by the Arealometer and standard methods are noteworthy with respect to both frequency and magnitude. The general slope of all three trend lines is similar but it is steeper for the series of values by the standard method and Arealometer than for the Causticaire maturity index. These findings show that, although the values for fiber maturity as determined by either the Arealometer or standard method of test agreed very closely with the Causticaire maturity values in the case of a few cottons, they differed in more or less degree for most of the cottons, and quite widely for some of them.

In this connection, it also is of interest to note from figure 11 that the minimum value of fiber maturity, as determined by each of the three methods of test, was identified with the same sample of cotton. However, the maximum value of fiber maturity, as determined by the three methods, did not apply in all cases to the same sample.

Although all the correlation analyses referred to in this chapter were not identified with the same group of cottons and all the correlation values obtained for the different pairs of alternative measures of fiber maturity are not precisly comparable, a summary tabulation of such values is of general interest, as follows:

Alternative measures	Cottons	(R)
Arealometer and standard maturity	71	+0.889
Causticaire and Arealometer maturity	71	+ .881
Causticaire and standard maturity	72	+ .895
Causticaire and standard maturity	319	+ .752

In the light of the foregoing discussion, it is apparent that various fluctuations and disparities occurred in the corresponding values of the three alternative maturity measures for the various series of cottons, even for the more common group of 71 or 72 cottons selected to cover a wide range of fiber maturity and fineness. Obviously, such variations go to explain any detectable differences found in the comparative significance of the respective measures of fiber maturity from the standpoint of nep count of card web, yarn appearance, and yarn strength.

As will be shown later in this report, on the basis of results obtained from multiple correlation analyses representing 52 selected cotton, Causticaire maturity index was found to possess more significance toward nep count of card web, yarn appearance, and yarn strength than either percentage of mature fibers (standard method) or immaturity ratio (Arealometer). The superiority of the Causticaire maturity index over the two other measures of fiber maturity was very appreciable in the case of nep count of card web and yarn appearance. Immaturity ratio (Arealometer) showed somewhat more significance from the standpoint of nep count of card web, yarn appearance, and yarn strength than did percentage of mature fibers (standard method), as also will be shown later in this report.

RELATION OF FIVE COTTON-FIBER PROPERTIES, INCLUDING ALTERNATIVE CAUSTICAIRE, AREALOMETER, AND STANDARD MATURITY MEASURES, TO THREE DEPENDENT VARIABLES

By using the data representing 52 cottons selected to represent wide ranges of fiber maturity and fineness, with more or less equal distribution of samples throughout the entire ranges of those fiber properties, and processed at one rate of card production (9-1/2 pounds per hour), multiple correlation analyses were made of the relation of five fiber properties to each of three dependent variables, namely, number of neps per 100 square inches of card web, appearance of 36s carded yarn, and skein strength of 36s yarn. Three parallel analyses were made in each case, including three alternative measures

of fiber maturity, as follows: Causticaire maturity index, Arealometer immaturity ratio, and percentage of mature fibers (standard method). Upper half mean length, length uniformity ratio, fiber fineness (weight per inch by the array method), and fiber strength comprised the other four fiber properties that were common to all analyses.

The statistical values, representing data identified with the various independent and dependent variables used in the multiple correlation analyses for those 52 cottons, are summarized in table 1. Comparative values for the Causticaire and standard maturity measures, representing this series of selected cottons, are shown in the following tabulation:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	78.7	± 6.0	48	87	39
(2) Standard	83.2	± 6.5	58	94	36
Difference (1)-(2)	-4.5	- .5	-10	-7	+3

Comparative values for Causticaire maturity index and Arealometer immaturity ratio, representing the same 52 cottons, are indicated in the tabulation below:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Arealometer 1/	74.4	± 8.0	39	92	53
(2) Standard	83.2	± 6.5	58	94	36
Difference (1)-(2)	-8.8	+ 1.5	-19	-2	+17

1/ For the purpose and convenience of this comparison, the values for Arealometer immaturity ratio were converted into percentage of mature fibers by the relationship reported in the Spinlab Instruction Manual (16).

A corresponding comparison of the values for Causticaire maturity index and Arealometer immaturity ratio, representing the same 52 cottons, is shown as follows:

Method	Mean	St. Dev.	Min.	Max.	Range
(1) Causticaire	78.7	± 6.0	48	87	39
(2) Arealometer 1/	74.4	± 8.0	39	92	53
Difference (1)-(2)	+4.3	- 2.0	+9	-5	-14

1/ See footnote above.

The values of the coefficients of correlation ($\bar{R}$), as obtained from the 9 multiple correlation analyses conducted on the data for this series of 52 selected cottons, are summarized in table 4. The percentages of variance (R^2 x 100) explainable in each dependent variable by the five fiber properties, including three alternative measures of fiber maturity, are shown in table 5. And the values for the standard error of estimate ($\bar{S}$) for each dependent variable, as based on each combination of measures for the five fiber properties, are listed in table 6.

Nep count of card web. By including the percentage of mature fibers (standard method) in the analysis, the five fiber properties showed a coefficient of multiple correlation ($\bar{R}$) of 0.648 with number of neps per 100 square inches of card web. When substituting immaturity ratio (Arealometer) for the standard measure of maturity, the $\bar{R}$ value was 0.691 or an increase of 0.043 over that obtained when percentage of mature fibers was considered. By using Causticaire maturity index in the analysis, the $\bar{R}$ value was 0.797 or an increase of 0.149 over that obtained with standard maturity and an increase of 0.106 over that with Arealometer immaturity ratio.

The amount of variance in nep count of card web explainable by the five fiber properties ($\bar{R}^2$ x 100) was 42.0 percent when percentage of mature fibers (standard method) was included in the analysis; 47.7 percent with immaturity ratio (Arealometer); and 63.5 percent with Causticaire maturity index. Thus, immaturity ratio explained 5.7 percent more variance in nep count of card web than did percentage of mature fibers (standard method) and Causticaire maturity index accounted for 21.5 percent more variance in neps than did the standard measure of maturity. Although both of these maturity measures exceeded the standard maturity one, the Causticaire maturity index explained 15.8 percent more variance in nep count of card web than did the Arealometer immaturity ratio.

In terms of number of neps per 100 square inches of card web, on the basis of the different combinations measures used for the five properties, the standard errors of estimate ($\bar{S}$) were as follows: $\pm$27.63 with percentage of mature fibers (standard method); $\pm$26.22 with immaturity ratio (Arealometer); and $\pm$21.91 with Causticaire maturity index. Thus, the $\bar{S}$ value with the measure of standard maturity included in the analysis was the largest of all, that with immaturity ratio being 1.41 units smaller and that with Causticaire maturity index being 5.72 units smaller. The $\bar{S}$ value with Causticaire maturity included was 4.31 units smaller than that for Arealometer maturity.

Appearance of 36s yarn. By including the percentage of mature fibers in the analysis, the five fiber properties gave a correlation coefficient ($\bar{R}$) of 0.616 with appearance of 36s yarn; when immaturity ratio was substituted, the coefficient was 0.635; and when the Causticaire maturity index was used, it was 0.720. Thus, as compared with the $\bar{R}$ value in the case of standard maturity, the $\bar{R}$ value identified with

Arealometer maturity was 0.019 larger and that with Causticaire maturity was 0.104 larger. On the basis of the $\bar{R}$ value associated with Arealometer maturity, the $\bar{R}$ value with Causticaire maturity index was 0.085 larger.

Percentage of mature fibers in conjunction with the other 4 fiber properties explained 38.0 percent of the variance in appearance of 36s yarn. When immaturity ratio was substituted, 40.4 percent of yarn appearance was accounted for and, when Causticaire maturity index was included, 51.8 percent was explained. On this basis, the Arealometer maturity measure explained 2.4 percent more variance in appearance of 36s yarn than did percentage of mature fibers (standard method) and Causticaire maturity index accounted for 13.8 percent more yarn-appearance variance than did percentage of mature fibers. Thus, Causticaire maturity index explained 11.4 percent more variance in 36s yarn appearance than did Arealometer immaturity ratio.

The values for standard error of estimate ($\bar{S}$) with respect to yarn appearance followed the same general trend as did the $\bar{R}$ and $\bar{R}^2 \times 100$ values, except for a reverse direction, that is, with percentage of mature fibers, the $\bar{S}$ value was ± 7.06; with immaturity ratio, it was ± 6.92; and with Causticaire maturity index, it was ± 6.22. As compared with the $\bar{S}$ value for standard maturity, therefore, the $\bar{S}$ value with Arealometer maturity was smaller by 0.14 and the one with Causticaire maturity was 0.84 smaller. Thus, the standard error of estimate value with Causticaire maturity index was 0.70 smaller than that with Arealometer immaturity ratio.

Strength of 36s yarn. The five fiber properties, including percentage of mature fibers, showed a multiple correlation ($\bar{R}$) of 0.938 skein strength of 36s yarn; when immaturity ratio was substituted, it was 0.944; and when Causticaire maturity index was used, it was 0.956. When using the $\bar{R}$ value with standard maturity as the basis of comparison, the $\bar{R}$ value with Arealometer maturity was 0.006 larger and with Causticaire maturity it was 0.018 larger. Thus, the $\bar{R}$ value with Causticaire maturity was 0.012 larger than that with immaturity ratio. Such differences as these, however, are too small to be of any practical significance. Yet, the fact that the direction of these small differences is consistently in line with that for the larger differences, as previously reported for nep count of card web and yarn appearance, is reassuring.

Percentage of mature fibers, together with the other four fiber properties, explained 88.0 percent of the variance in strength of 36s yarn. When immaturity ratio was included, the $\bar{R}^2 \times 100$ value was increased to 89.1 percent and, when Causticaire maturity index was included, it was increased to 91.6 percent. Thus, Arealometer maturity explained 1.1 percent more variance in yarn strength than did standard maturity whereas Causticaire maturity accounted for 3.6 percent more variance in this connection. Causticaire maturity index, therefore, accounted for 2.5 percent more variance in 36s yarn strength than did Arealometer immaturity ratio.

The five fiber properties, including percentage of mature fibers, gave a standard error of estimate ($\bar{S}$) of ± 3.71 pounds with skein strength of 36s yarn, as compared with ± 3.53 pounds when immaturity ratio was sub-

stituted and ± 3.12 pounds when Causticaire maturity index was used. Accordingly, the Arealometer maturity measure gave a standard error of estimate with respect to skein strength of 36s yarn which was 0.18 pound smaller than that by standard maturity, whereas Causticaire maturity furnished an $\bar{S}$ value 0.59 pound smaller than that of standard maturity. The difference between the latter two $\bar{S}$ values, therefore, was 0.41 pound in favor of the Causticaire maturity index over Arealometer immaturity ratio.

General considerations. As shown by the findings reported in table 4 for the relation of the five cotton fiber properties to nep count of card web, yarn appearance, and yarn strength, it will be noted that the coefficient of correlation was substantially larger with each dependent variable when Causticaire maturity index was included than when either the Arealometer immaturity ratio or percentage of mature fibers (standard method) was used. In each case where fiber maturity was expressed as immaturity ratio, the correlation coefficient was larger than that for percentage of mature fibers. The largest increase in $\bar{R}$ value for either the Causticaire or Arealometer measure over percentage of mature fibers was with nep count of card web, followed rather closely by that with yarn appearance. The increase in $\bar{R}$ value for Causticaire maturity index over immaturity ratio and percentage of mature fibers was quite large with those dependent variables. The differences between the $\bar{R}$ value identified with the three alternative maturity measures were comparatively small and negligible in the case of yarn strength.

The findings, as presented in table 5, show that the percentage of variance explainable in nep count of card web and yarn appearance was considerably more when Causticaire maturity index was used instead of either Arealometer immaturity ratio or percentage of mature fibers. The amount of explainable variance in number of card-web neps and yarn appearance was larger for immaturity ratio than for percentage of mature fibers. The corresponding differences for the alternative maturity measures were relatively small and negligible in terms of yarn strength.

Standard errors of estimate were smaller with each of the three dependent variables when Causticaire maturity index was used, instead of either Arealometer immaturity ratio or percentage of mature fibers by the standard method, as shown in table 6. The standard errors of estimate also decreased in every case with the use of immaturity ratio, as compared with percentage of mature fibers.

COMPARATIVE SIGNIFICANCE OF CAUSTICAIRE, AREALOMETER, AND STANDARD MATURITY MEASURES TO THREE DEPENDENT VARIABLES

The relative net importance of five fiber properties, including three alternative measures of maturity, to number of neps per 100 square inches of card web, to appearance of 36s yarn, and to skein strength of

36s yarn is revealed by the values and rank of the beta coefficients listed in table 7. Those findings were obtained from multiple correlation analyses representing the 52 American upland cottons selected to cover a wide range and general distribution of fiber fineness and maturity, as referred to in the previous chapter.

Nep count of card web. When percentage of mature fibers (standard method) was included in the analysis, each of the five fiber properties showed a statistically insignificant effect on number of neps per 100 square inches of card web for this selected series of 52 upland cottons, that is, all of the beta values were less than 3 times their respective standard errors. On the basis of magnitude of the beta values, however, percentage of mature fibers ranked second in importance toward nep count of card web.

With Causticaire maturity index included, all fiber properties failed to exert a statistically significant effect on nep count, except maturity index. The beta value for the Causticaire measure of fiber maturity was strongly significant in this instance, being approximately 6 times its standard error. Thus, of the five fiber properties considered, Causticaire maturity index ranked outstandingly first in importance toward nep count of card web.

In the analysis in which Arealometer immaturity ratio was used as the measure of fiber maturity, only immaturity ratio showed a statistically significant effect toward nep count of card web. This maturity measure, however, was barely statistically significant in this instance--its beta coefficient being only slightly larger than three times its standard error. On the basis of magnitude of the respective beta values, immaturity ratio ranked first in importance toward nep count of card web.

Yarn appearance. When using percentage of mature fibers (standard method) as the measure of fiber maturity in the analysis, all fiber properties made a statistically insignificant contribution to appearance of 36s yarn. On the basis of magnitude of the respective beta values, however, percentage of mature fibers ranked third in importance toward yarn appearance.

In the analysis containing maturity index, however, the Causticaire measure of fiber maturity proved to be strongly significant toward yarn appearance and, of the fiber properties considered, it ranked first in importance. The value of the beta coefficient for Causticaire maturity index in this case was nearly 4 times its standard error. All the other beta values obtained from this analysis were statistically insignificant.

With the third parallel analysis, the values of all beta coefficients representing the five fiber properties were statistically insignificant with respect to yarn appearance, including Arealometer immaturity ratio. On the basis of magnitude of the respective beta values, however, immaturity ratio ranked second in importance toward yarn appearance.

Yarn strength. Of the five fiber properties included in the analysis, percentage of mature fibers (standard method) ranked fourth in importance toward strength of 36s yarn. The value of its beta coefficient, however, was barely statistically significant, that is, it was only slightly larger than 3 times its standard error.

In the analysis of the five fiber properties, the Causticaire maturity index ranked third in importance to yarn strength. The beta value for the Causticaire maturity index in this instance was strongly significant--being nearly 6 times its standarderror.

Immaturity ratio (Arealometer) also ranked third in importance toward strength of 36s yarn, its beta value being 4 times its standard error.

General considerations. For the purpose of easy comparison, the values and rank of the beta coefficients obtained for the three alternative measures of cotton-fiber maturity in connection with nep count of card web, yarn appearance, and yarn strength are summarized as follows:

Maturity measure	Beta value	Rank of importance
(With nep count of card web)		
Causticaire maturity index	-0.822 ± 0.142	1
Arealometer immaturity ratio	$+ .571 \pm .186$	1
Percentage of mature fibers	$- .359^{*} \pm .182$	2
(With appearance of 36s yarn)		
Causticaire maturity index	$+0.613 \pm 0.163$	1
Arealometer immaturity ratio	$- .314^{*} \pm .199$	2
Percentage of mature fibers	$+ .154^{*} \pm .188$	3
(With skein strength of 36s yarn)		
Causticaire maturity index	$+0.401 \pm 0.069$	3
Arealometer immaturity ratio	$- .344 \pm .085$	3
Percentage of mature fibers	$+ .269 \pm .083$	4

In the foregoing tabulations, an asterisk on a beta value indicates that it is statistically insignificant; that is, the magnitude of the beta value is less than 3 times its standard error.

The plus or minus sign on each beta value indicates the direction of the contribution of the measure of fiber maturity to a particular dependent variable. It will be noted that the sign on the beta value of the Arealometer immaturity ratio for a given dependent variable is opposite to that for Causticaire maturity index and that for percentage of mature fibers (standard method). That this is true is due to the fact that the scale of measurement and expression for the Arealometer immaturity ratio runs in the opposite direction to those for Causticaire maturity index and percentage of mature fibers.

It is of interest to observe from the data presented in table 7, as referred to previously in this chapter, that the Causticaire maturity index possessed more significance toward nep count of card web, appearance of 36s yarn, and strength of 36s yarn than did either Arealometer immaturity ratio or percentage of mature fibers. Also, it is of interest to note that the immaturity ratio possessed more significance to those dependent variables than did percentage of mature fibers.

The beta values for the Causticaire maturity index were statistically significant with all three dependent variables, and they were consistently larger than the corresponding ones for Arealometer immaturity ratio and percentage of mature fibers. Immaturity ratio furnished one beta value in this series of three analyses that was statistically insignificant, namely, the one with appearance of 36s yarn used as the dependent variable.

As shown by table 7 and the foregoing tabulations, the three alternative measures of fiber maturity definitely ranked in order of importance to yarn appearance as follows: (1) Causticaire maturity index, (2) Arealometer immaturity ratio, and (3) percentage of mature fibers (standard method). Although in the cases of nep count of card web and yarn strength, Causticaire maturity index and Arealometer immaturity ratio occupied the same rank of importance to those respective dependent variables, as determined by each series of five beta values, the relationship and contribution identified with the Causticaire maturity index in those instances were stronger than those of the Arealometer maturity measure, as indicated by magnitude of the values for the respective beta coefficients.

RELATION OF SIX COTTON-QUALITY ELEMENTS, INCLUDING CAUSTICAIRE FINENESS AND MATURITY VERSUS MICRONAIRE FINENESS AND STANDARD MATURITY, TO FIVE DEPENDENT VARIABLES

The findings obtained from multiple correlation analyses representing the 319 cottons from the 1951 crop are shown in table 8 and those for the 309 cottons, crop of 1952, are listed in table 9. Values for coefficient of correlation ($\bar{R}$), the percentage of variance explained ($\bar{R}^2$ x 100), and the standard error of estimate ($\bar{S}$), identified with each of the 5 dependent variables considered, are arranged in those tables to

permit ready comparison of the statistical results obtained when the Causticaire fiber fineness and Causticaire maturity measures were included, and when the measures of Micronaire fineness and percentage of mature fibers were used in parallel analyses.

Results with samples from 1951 crop. Referring to table 8, it will be seen that better results were obtained from the multiple correlation analyses, on the whole, when the Causticaire fiber fineness and maturity measures were used than when values of Micronaire fineness and percentage of mature fibers (standard method) were included. In other words, when the measures of Causticaire fineness and maturity were included in the analyses, the coefficients of correlation were larger with appearance of 22s yarn, with collective appearance of all yarn sizes spun, with strength of 22s yarn, and with count-strength product of all yarn sizes; the amount of variance explained in those dependent variables was larger; and the standard errors of estimate with those dependent variables were smaller, as compared with corresponding values of correlation obtained when the alternative measures of Micronaire fineness and standard maturity were included in the analyses. The largest differences in paired values occurred when appearance of 22s yarn was used as the dependent variable. Although the paired differences were small for the other dependent variables mentioned, they were consistent in both magnitude and direction.

The only inconsistent results to those outlined above occurred when number of neps per 100 square inches of card web was used as the dependent variable. In this instance, slightly better correlation results were obtained from the multiple analysis with Micronaire fineness and percentage of mature fibers than with Causticaire fineness and maturity. However, as the paired differences were small, no particular significance is attached to them and more especially so in view of the highly variable and complex nature involved in the formation of neps. Furthermore, as shown earlier in this report, Causticaire maturity index exerted a statistically significant effect on nep count of card web, whereas percentage of mature fibers (standard method) did not.

As shown earlier in this report for 52 selected upland cottons, much better correlation values were obtained with nep count of card web when Causticaire maturity values were included in the analysis than when percentage of mature fibers (standard method) was used. It should be pointed out, however, that the range in the number of card-web neps of that study was extremely high being 263 (4 to 267); that the mean number of neps for the 52 selected samples was 22.2; and that the standard deviation of nep count also was extremely high, being ±35.9. (See table 1.) By comparison, for the 319 samples of the 1951 study, table 2, the range in the number of card-web neps was much smaller, being only 117 (3 to 120), the mean number of neps was 27.2, and the standard deviation of the nep count was extremely small, being only ±13.1. Moreover, the 52 samples used by Burley and Bartmess in their preliminary study possessed a much wider range with respect to fiber fineness and maturity, as well as a much better distribution of

samples over the entire range of those two fiber properties, than did the samples used in this segment of the present study. Such disparities are important factors influencing correlation results and comparisons, as considered in this report.

Results with samples from the 1952 crop. The parallel results obtained from multiple correlation analyses of the data, representing the 309 cottons from the 1952 crop, as shown in table 9, were approximately the same, whether Causticaire fineness and maturity measures were used, or whether Micronaire fineness and standard maturity values were included. Limitations in the range and distribution of values for fiber fineness and maturity, as well as for nep count of card web, occurred with the 1952 series of samples as was pointed out previously for the 1951 samples. If anything, an even greater degree of restriction existed in these respects for the 1952 samples than for the 1951 samples. For example, for the 1952 samples, the range of number of neps per 100 square inches of card web was extremely small, being only 75 (3 to 78), the mean value of nep count was only 15.7, and the standard deviation for number of neps per 100 square inches of card web was only ± 9.6. (See table 3.) As previously stated, restrictions and limitations of this kind are important factors influencing such correlation results and comparisons.

RELATIVE SIGNIFICANCE OF ALTERNATIVE PAIRS OF FINENESS AND MATURITY MEASURES TO FIVE DEPENDENT VARIABLES

The comparative net importance of the respective elements of raw-cotton quality considered to the various dependent variables, as determined by beta coefficients derived from multiple correlation analyses, is shown in table 10 for the 319 cottons of the 1951 crop and in table 11 for the 309 cottons of the 1952 crop. Values have been tabulated in parallel manner for ease in making comparisons of the relative contribution of Causticaire fiber fineness and Causticaire maturity versus that of Micronaire fineness and percentage of mature fibers (standard method).

Results with Samples of 1951 Crop

Nep count of card web. The measures of Causticaire fiber fineness and Micronaire fineness made a statistically significant contribution to number of neps for 100 square inches of card web and each ranked first in importance, of the factors considered, to that dependent variable. (See table 10.) Causticaire maturity index made a statistically significant contribution to nep count of card web and ranked second in importance of the factors studied, whereas percentage of mature fibers (standard method) showed a statistically insignificant contribution to nep count of card web and ranked third.

Yarn appearance. With respect to the appearance of 22s yarn, Causticaire fineness and Micronaire fineness each made a statistically significant contribution and ranked first in importance of the factors considered. Both Causticaire maturity and standard maturity made a statistically insignificant contribution to this dependent variable and each assumed a rank of second place. It is of interest to note, however, that the beta value for Causticaire maturity was almost statistically significant in this case. By comparison with the figures for percentage of mature fibers (standard method), the beta value for Causticaire maturity was approximately twice as large and its standard error of measurement was smaller.

With respect to the collective appearance of all yarn sizes spun, Causticaire and Micronaire fineness made a statistically significant contribution and each ranked second in importance of the factors considered. Causticaire maturity made a statistically significant contribution in this case and ranked third, whereas percentage of mature fibers (standard method) failed to exert a statistically significant effect, and ranked fourth.

Yarn strength. With regard to strength of 22s yarn, Causticaire fineness made a statistically significant contribution and ranked third in importance of the factors studied. Micronaire fineness, on the other hand, failed to exert a statistically significant effect in this case and ranked fourth. Both Causticaire maturity and percentage of mature fibers (standard method), however, were without statistical significance to strength of 22s yarn and both measures ranked sixth or last in importance of the factors considered.

As to count-strength product of all yarn sizes spun, Causticaire fineness and Micronaire fineness made a statistically significant contribution and each ranked fourth in order of importance. Both Causticaire maturity and standard maturity failed to produce a statistically significant effect on count-strength product and each occupied sixth place in importance of the factors studied.

Results with Samples of 1952 Crop

Neps in card web. Table 11 shows that Causticaire fineness ranked first in importance to number of neps per 100 square inches of card web and Micronaire fineness, second. Percentage of mature fibers (standard method) ranked first in magnitude of effect on nep count of card web, whereas Causticaire maturity ranked second.

Yarn appearance. With respect to appearance of 22s yarn, Micronaire fineness ranked first and Causticaire fineness, second. On the other hand, Causticaire maturity produced a statistically significant effect on appearance of 22s yarn and ranked first in importance of the factors studied, whereas percentage of mature fibers (standard method) failed to make a statistically significant contribution and ranked second.

As to collective appearance of all yarn sizes spun, the findings obtained were similar to those cited above for appearance of 22s yarn. Micronaire fineness outranked Causticaire fineness in importance, by one step. Causticaire maturity, however, showed a statistically significant effect and ranked second in importance of the factors considered, whereas percentage of mature fibers (standard method) failed to produce a statistically significant effect and ranked seventh.

Yarn strength. With regard to strength of 22s yarn, Causticaire fineness made a statistically significant contribution and ranked third in importance of the factors studied. Micronaire fineness, however, caused a statistically insignificant effect and ranked sixth or last. On the other hand, percentage of mature fibers (standard method) exerted a statistically significant effect on strength of 22s yarn, ranking third of the factors included in the analysis, whereas Causticaire maturity failed to make a statistically significant contribution and ranked sixth or last.

In the case of count-strength product of all yarn sizes spun, the findings obtained were similar to those listed above for strength of 22s yarn, that is, Causticaire fineness caused a statistically significant effect and ranked third, as compared with a statistically insignificant effect and seventh place of rank for Micronaire fineness. Causticaire maturity, on the other hand, made a statistically insignificant contribution to count-strength product and ranked seventh, whereas percentage of mature fibers (standard method) showed a statistically significant effect and ranked fourth.

DISCUSSION

The comparative findings reported herein, as obtained from multiple and simple correlation analyses on data representing two large series of American upland cottons in commercial production, crop years of 1951 and 1952, give added confidence to the relative merits of the new Causticaire measures for cotton-fiber fineness and maturity. It was not expected, however, that the Causticaire measures would prove as superior to the respective standard measures under the conditions of these analyses, as shown by Burley and Bartmess (5) and as shown earlier in this report for 52 upland cottons selected to represent wide ranges of fiber maturity and fineness, with general distribution of values for those fiber properties throughout their entire ranges.

Effect of rate of card production on nep count, yarn appearance, and yarn strength. The range in number of neps per 100 square inches of card web and the standard deviation of the nep counts were very much greater for the 52 selected samples previously referred to than for the 319 cottons from the 1951 crop and for the 309 cottons from the 1952 crop, as shown by the values tabulated on the following page:

Cottons	Nep count per 100 square inches of card web				
	Mean	Min.	Max.	Range	S.D. 1/
52 selected	22.2	4	267	263	± 35.9
1951 series	27.2	3	120	117	± 13.3
1952 series	15.7	3	78	75	± 9.6

1/ S. D. = Standard deviation.

The range in number of neps per 100 square inches of card web and the standard deviation of those nep counts would have been greater for the 319 cottons, crop of 1951, and for the 309 cottons, crop of 1952, had all the samples been processed at one rate of card production, say, 9-1/2 pounds per hour. Instead, however, three rates of card production were used in processing those two series of samples, as follows:

Rate of Carding

1951 series	Staple length Inches	Cottons Number	Cottons Percent
12-1/2 lb. per hr.	15/16 and shorter	39	12.2
9-1/2 lb. per hr.	31/32 to 1-1/16	226	70.8
6-1/2 lb. per hr.	1-3/32 through 1-1/4	54	17.0
		319	100.0
1952 series			
12-1/2 lb. per hr.	15/16 and shorter	33	10.7
9-1/2 lb. per hr.	31/32 to 1-1/16	231	74.7
6-1/2 lb. per hr.	1-3/32 through 1-1/4	45	14.6
		309	100.0

On the basis of correlation findings shown by Webb and Richardson (26) and (27), a larger number of neps per 100 square inches of card web would be expected with the group of short cottons processed at 12-1/2 pounds per hour than if they had been carded at 9-1/2 pounds per hour. Likewise, a smaller number of neps would be expected with the group of long cottons carded at 6-1/2 pounds per hour than if they had been carded at 9-1/2 pounds per hour. Thus, by processing the cottons of the three staple-length categories at different rates of card production, the range in the number of neps per 100 square inches of card web was sharply restricted which, in effect, reduced the degree of relationship between nep count and the fiber properties from that which otherwise would have been present and which, in turn, prevented Causticaire maturity and fineness measures from showing up to their fullest or best advantage.

Effect of distribution of data on correlation results pertaining to nep count, yarn appearance, and yarn strength. Reference has been made to the effect that the statistical values obtained from multiple correlation analyses, as here reported for the 1951 and 1952 crops, were smaller and less significant than otherwise would have been the case, because of limitations in the ranges of the data serving as the independent and dependent variables, and because there was an appreciable concentration of observations around the mean values of the respective series of cottons. The extent to which a concentration existed in the values of Causticaire fiber fineness and Micronaire fineness for the 1951 samples is shown in figure 5; and that with respect to Causticare maturity index and percentage of mature fibers for the same series of cottons is shown in figure 7.

In an effort to determine the effect of the distribution factor with respect to fiber fineness and maturity on multiple correlation values, 18 supplementary analyses were made on the data representing the 1951 cottons. The usual 6 elements of raw-cotton quality, including alternative measures for fiber fineness and maturity, were used as independent variables, following the pattern for the regular analyses previously reported. Similar analyses were made with each of 3 dependent variables, namely, number of neps per 100 square inches of card web, appearance of 22s carded yarn, and strength of 22s yarn. Parallel analyses were made with each dependent variable: One, with the 6 cotton-quality elements including Micronaire fineness and percentage of mature fibers (standard method); and the other, with Causticaire fineness and maturity substituted for the alternative measures.

The data identified with the independent and dependent variables used in one set of analyses represented 25 cottons selected from the 1951 series on the basis of equal steps of 0.1 micrograms (weight per inch) over the range of 2.7 micrograms to 5.6 micrograms, as determined by the Causticaire method. In the second case, 25 cottons were selected from the same series of cottons on the basis of equal steps of 1 unit maturity index over the range of 64 to 85 maturity index, as evaluated by the Causticaire method. And, the third case represented a combination of the first two; that is 50 cottons possessing the intervals and ranges with respect to Causticaire fineness and maturity, as indicated above.

No results are presented in this report from the supplementary analyses, when Causticaire fineness and maturity were used separately; nor when Micronaire fineness and percentage of mature fibers (standard method) were used individually. Results are presented in this report only when Causticaire fineness and Causticaire maturity measures were used jointly with the other fiber properties, and when Micronaire fineness and standard maturity were used collectively.

Referring to table 12, identified with the two Causticaire measures and nep count of card web, it will be seen that the coefficient of correlation ($\bar{R}$) was 0.560 for the entire series of 319 cottons and 0.587

for the 50 selected samples, or an increase of 0.027. This means that 3.0 percent more variance in nep count of card web was explainable by the factors used in the case of the selected samples than for the whole series of cottons. The standard error of estimate is shown to be appreciably larger for the 50 selected cottons than for the 319 cottons, as reasonably might be expected in this instance.

As also listed in table 12, the coefficient of correlation ($\overline{R}$) with appearance of 22s yarn was 0.475 for the entire series of cottons and 0.734 for the 50 selected cottons, or an increase of 0.259. Thus, 31 percent more variance in yarn appearance was accounted for by the factors when the stratified samples were used than when all the samples were included. In this case, the standard error of estimate was slightly smaller for the 50 selected cottons than for the entire 319 cottons.

In the case of strength of 22s yarn, as also shown in table 12, no appreciable differences were noted in the $\overline{R}$ and $\overline{R}^2$ x 100 values for the two series of samples.

In table 13, corresponding correlation values and differences for each of three dependent variables are shown, when Micronaire fineness and percentage of mature fibers (standard method) were included among the factors studied. The differences shown between the paired correlation values, as identified with the 50 selected cottons and the entire series of 319 cottons, are similar in magnitude and direction to those listed in table 12, when the Causticaire measures of fiber fineness and maturity were included.

A comparison of the correlation values listed in tables 12 and 13 for the 50 selected cottons is shown in table 14, as identified with the inclusion in the paired analyses of the alternative measures of cotton-fiber fineness and maturity. The magnitude and direction listed for the differences representing the paired values are in line with what might be expected on the basis of the values previously listed.

From the foregoing, it is evident that the more uniform the distribution of data throughout the range with respect to cotton-fiber fineness and maturity the better were the correlation values obtainable with nep count of card web and yarn appearance. Thus, some of the disparity between the correlation values shown for the 52 selected cottons and those listed for the 1951 and 1952 series may be explained by differences in the distribution of the basic data used in the respective analyses. Explanation for a considerable amount of the disparity in the correlation values is due to the greater range of fiber fineness and fiber maturity possessed by the selected series of 52 cottons. Obviously, the inclusion in a series of samples of a sizable number of extremely fine and coarse-fibered cottons and of highly mature and immature ones for analysis on the relation of cotton-fiber properties to nep count of card web and to yarn appearance offers an

opportunity for better correlation values, and more significant evaluations with respect to Causticaire maturity index than to either Arealometer immaturity ratio or percentage of mature fibers (standard method). This position seems well taken by virtue of the fact that the Causticaire method has been found to give more accurate, comparable, and significant evaluation of fiber maturity for cotton throughout the entire range of fiber maturity and fineness, especially with cottons possessing relatively large or small percentages of thin-walled fibers and small or large values for fiber weight per inch, than have the Arealometer and standard maturity methods.

General considerations. In considering the disparities in results reported, it seems well to emphasize again the fact that, in the case of the 52-cotton series, the true or original relations of the measured fiber properties to nep count of card web and yarn appearance were maintained by the constant rate of card production, and that the results obtained from all cottons in those respects were comparable. However, for the 1951 and 1952 series of cottons, the relations of the measured fiber properties to nep count of card web and yarn appearance were modified and reduced by the factor of different rates of card production used, so the results obtained from all cottons in those two series were not strictly comparable.

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APPENDIX

Table 1.--Summary of statistical values, representing data identified with the various independent and dependent variables used in multiple correlation analyses, for 52 upland cottons selected to cover wide ranges of fiber fineness and maturity, with more or less equal distribution of samples throughout the entire ranges of those fiber properties 1/

Factors used in analysis, as--	Observations 2/	Value for--				
		Mean	Standard deviation 3/	Maximum	Mimimum	Range
	Number					
Dependent variables:						
Neps per 100 sq. in of card web .... number	52	22.2	± 35.9	267	4	263
Appearance of 36s yarn .... index	52	100.2	± 8.9	110	60	50
Strength of 36s yarn .... pounds	52	62.0	± 10.6	86	41	45
Independent variables:						
Upper half mean length .... inches	52	1.02	± .08	1.18	.84	.34
Length uniformity ratio .... index	52	78.4	± 2.6	83	73	10
Fiber strength .... 1,000 lb. per sq. in.	52	78.8	± 7.6	97	64	33
Array fiber fineness (weight per inch).......... micrograms	52	4.24	± .76	6.3	2.4	3.9
Mature fibers (standard method).......... percent	52	83.2	± 6.5	94	58	36
Causticaire maturity .... index	52	78.7	± 6.0	87	48	39
Arealometer immaturity .... ratio	52	1.93	± .23	2.94	1.44	1.50

1/ Data were listed by Burley and Bartmess in their preliminary report (5), except for Arealometer immaturity ratio.

2/ Values shown indicate the number of observations used in each multiple correlation analysis.

3/ In terms of units of measure for the respective variables.

Table 2.--Summary of statistical values, representing data identified with the various independent and dependent variables used in multiple and simple correlation analyses, for 319 selected cottons, crop year 1951

Factors used in analysis, as--	Obser-vations 1/	Value for-- Mean	Standard deviation Absolute 2/	Standard deviation Relative 3/	Maximum	Minimum	Range
	Number			Percent			
Dependent variables:							
Neps per 100 square inches of card web ....number	319	27.2	± 13.1	±48.2	120	3	117
Appearance of 22s carded yarn ....index	319	106.4	± 9.0	± 8.5	120	80	40
Appearance of all sizes of carded yarn ....index	638	102.6	± 10.5	±10.2	120	60	60
Strength of 22s carded yarn ....pounds	319	114.5	± 14.7	±12.8	162	76	86
Count-strength product of all yarn sizes ....csp units	638	2,300.3	±369.1	±16.0	3,564	1,250	2,314
Independent variables:							
Grade of cotton ....index	319	97.0	± 5.7	± 5.9	104	75	29
Upper half mean length ....inches	319	1.05	± .08	± 7.6	1.26	.78	.48
Length uniformity ratio ....percent	319	79.1	± 1.2	± 1.5	83	75	8
Fiber strength ....1000 lb. per sq. in.	319	83.7	± 6.3	± 7.5	103	65	38
Micronaire fiber fineness (weight per inch)......micrograms	319	4.25	± .46	±10.8	5.8	2.8	3.0
Causticaire fiber fineness (weight per inch).....micrograms	319	4.04	± .48	±11.9	5.6	2.7	2.9
Mature fibers (standard method) ....percent	319	82.4	± 4.5	± 5.5	92	64	28
Causticaire fiber maturity ....index	319	78.8	± 3.2	± 4.1	86	62	24
Yarn size ....number	638	33.8	± 14.4	±42.6	50	14	36

1/ Value shown indicates the number of observations used in each multiple or simple correlation analysis.

2/ In terms of units of measure for the respective variables.

3/ Value of absolute standard deviation divided by mean value of respective variable, multiplied by 100.

Table 3.--Summary of statistical values, representing data identified with the various independent and dependent variables used in multiple and simple correlation analyses, for 309 cottons, crop year 1952

Factors used in analysis, as--	Observations 1/	Value for-- Mean	Standard deviation: Absolute 2/	Standard deviation: Relative 3/	Maximum	Minimum	Range
	Number			Percent			
Dependent variables:							
Neps per 100 square inches of card web ....number	309	15.7	± 9.6	±61.1	78	3	75
Appearance of 22s carded yarn ....index	309	108.8	± 8.2	± 7.5	120	70	50
Appearance of all sizes of carded yarn ....index	618	103.9	± 10.1	± 9.7	120	70	50
Strength of 22s carded yarn ....pounds	309	111.4	± 13.2	±11.8	160	77	83
Count-strength product of all yarn sizes ....csp units	618	2,222.6	±351.3	±15.8	3,520	1,400	2,120
Independent variables:							
Grade of cotton ....index	309	98.9	± 4.4	± 4.4	105	83	22
Upper half mean length ....inches	309	1.05	± .07	± 6.7	1.24	.76	.48
Length uniformity ratio ....percent	309	79.5	± 1.2	± 1.5	84	77	7
Fiber strength ....1,000 lb. per sq. in.	309	85.1	± 5.7	± 6.7	104	70	34
Micronaire fiber fineness (weight per inch) .....micrograms	309	4.37	± .43	± 9.8	5.6	2.6	3.0
Causticaire fiber fineness (weight per inch) ....micrograms	309	4.23	± .42	± 9.9	5.4	2.7	2.7
Mature fibers (standard method) ....percent	309	81.6	± 4.8	± 5.9	91	55	36
Causticaire fiber maturity ....index	309	79.4	± 3.1	± 3.9	88	58	30
Yarn size ....number	618	34.0	± 14.4	±42.3	50	14	36

1/ Value shown indicates the number of observations used in each multiple or simple correlation analysis.

2/ In terms of units of measure for the respective variables.

3/ Value of absolute standard deviation divided by mean value of respective variable, multiplied by 100.

Table 4.--Comparison of coefficients of correlation obtained from multiple correlation analyses for five cotton-fiber properties, including alternative measures of maturity, with nep count of card web, with yarn appearance, and with yarn strength, representing 52 selected cottons 1/

Dependent variable	Observations	Coefficient of correlation from analysis with 5 factors, including--					
		Percentage of mature fibers (Standard method)	Maturity index (Causticaire)	Immaturity ratio (Arealometer)	Difference (4) - (3)	Difference (5) - (3)	Difference (4) - (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Number						
Nep count of card web....	52	0.648 ± 0.081	0.797 ± 0.051	0.691 ± 0.073	+0.149	+0.043	+0.106
Appearance of 36s yarn...	52	.616 ± .087	.720 ± .067	.635 ± .084	+ .104	+ .019	+ .085
Strength of 36s yarn.....	52	.938 ± .017	.956 ± .012	.944 ± .015	+ .018	+ .006	+ .012

1/ In the respective correlation analyses, measures of five fiber properties of raw cotton were used as follows: Upper half mean length, length uniformity ratio, fiber strength, fiber fineness (wt. per in. by the array method), and fiber maturity expressed either as percentage of mature fibers (Standard method), or as maturity index (Causticaire), or as immaturity ratio (Arealometer).

Table 5.--Comparison of amounts of variance in nep count of card web, yarn appearance, and yarn strength explainable by five cotton-fiber properties, including alternative measures of maturity, representing 52 selected cottons 1/ 2/

Dependent variable	Observations	Variance in dependent variable explained by 5 factors, including--					
		Percentage of mature fibers (Standard method)	Maturity index (Causticaire)	Immaturity ratio (Arealometer)	Difference (4) - (3)	Difference (5) - (3)	Difference (4) - (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Number	Percent	Percent	Percent	Percent	Percent	Percent
Nep count of card web....	52	42.0	63.5	47.7	+21.5	+5.7	+15.8
Appearance of 36s yarn...	52	38.0	51.8	40.4	+13.8	+2.4	+11.4
Strength of 36s yarn.....	52	88.0	91.6	89.1	+ 3.6	+1.1	+ 2.5

1/ See footnote 1, table 8.

2/ Coefficient of determination ($\bar{R}^2$) obtained from each correlation analysis multiplied by 100.

Table 6.--Standard errors of estimate for nep count of card web, yarn appearance, and yarn strength on the basis of five cotton-fiber properties, including alternative measures of maturity, representing 52 selected cottons 1/ 2/

Dependent variable	Observations	Standard error of estimate on the basis of 5 factors, including--					
		Percentage of mature fibers (Standard method)	Maturity index (Causticaire)	Immaturity ratio (Arealometer)	Difference (4) - (3)	Difference (5) - (3)	Difference (4) - (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Number						
Nep count of card web....	52	± 27.63	± 21.91	± 26.22	-5.72	-1.41	-4.31
Appearance of 36s yarn...	52	± 7.06	± 6.22	± 6.92	- .84	- .14	- .70
Strength of 36s yarn.....	52	± 3.71	± 3.12	± 3.53	- .59	- .18	- .41

1/ See footnote 1, table 8.

2/ Unit of standard error varies with the dependent variable. For nep count of card web, the result is in terms of number of neps per 100 square inches; for yarn appearance, it refers to index units of yarn appearance; and for yarn strength, it is in units of pounds.

Table 7.--Relative net importance of five fiber properties of raw cotton, including alternative measures of maturity, to neps in card web, to yarn appearance, and to yarn strength, as evaluated by multiple correlation analysis, representing 52 selected cottons 1/

Variable	Observations	Analysis with 5 factors, giving-- Beta coefficients, including-- Percentage of mature fibers (Standard method)	Maturity index (Causticaire)	Immaturity ratio (Arealometer)	Rank of importance, including-- Percentage of mature fibers (Standard method)	Maturity index (Causticaire)	Immaturity ratio (Arealometer)
	Number						
Neps per 100 square inches of card web with:	52						
Fiber weight per inch (array)		-0.563* ± 0.303	-0.015* ± 0.240	-0.393* ± 0.281	1	4	2
Fiber maturity		- .359* ± .182	- .822 ± .142	+ .571 ± .186	2	1	1
Fiber strength		- .266* ± .141	- .116* ± .110	- .123* ± .148	3	3	5
Length uniformity ratio		+ .254* ± .129	+ .181* ± .103	+ .253* ± .122	4	2	3
Upper half mean length		- .235* ± .232	- .011* ± .183	- .230* ± .211	5	5	4
Appearance of 36s yarn with:	52						
Fiber weight per inch (array)		+ .497* ± .314	- .045* ± .275	+ .353* ± .300	1	4	1
Fiber strength		+ .379* ± .145	+ .227* ± .127	+ .285* ± .158	2	3	3
Fiber maturity		+ .154* ± .188	+ .613 ± .163	- .314* ± .199	3	1	2
Length uniformity ratio		- .113* ± .134	- .045* ± .118	- .108* ± .130	4	5	4
Upper half mean length		- .048* ± .240	- .272* ± .210	- .073* ± .225	5	2	5
Strength of 36s yarn with:	52						
Fiber weight per inch (array)		- .472 ± .138	- .629 ± .116	- .512 ± .128	1	1	1
Fiber strength		+ .461 ± .064	+ .420 ± .053	+ .393 ± .068	2	2	2
Upper half mean length		+ .314* ± .106	+ .251* ± .088	+ .337 ± .096	3	4	4
Fiber maturity		+ .269 ± .083	+ .401 ± .069	- .344 ± .085	4	3	3
Length uniformity ratio		+ .014* ± .059	+ .038* ± .050	+ .008* ± .056	5	5	5

1/ The plus or minus sign before a beta coefficient indicates the direction of the net contribution of the independent variable to the dependent variable.

* Statistically insignificant, being less than 3 times its standard error.

Table 8.--Summary of statistical values obtained from multiple correlation analyses for six elements of raw-cotton quality, including alternative measures of fiber maturity and fiber fineness, with neps in card web, with yarn appearance, and with yarn strength, representing 319 selected cottons, crop year of 1951

Variables used in analysis, as--	Independent variables 1/	Obser-vations	Value for-- Coefficient of correlation ($\bar{R}$)	Variance explained ($\bar{R}^2$ x 100)	Standard error of estimate ($\bar{S}$) Absolute	Relative
	Number	Number		Percent	2/	Percent 3/
Number of neps per 100 square inches of card web with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	319	0.576 ± 0.037	33.2	±10.7	±39.4
(2) Causticaire maturity and fineness substituted for alternative measures	6	319	.560 ± .038	31.4	±10.9	±40.0
Difference (2) - (1)	-	--	- .016	- 1.8	+ .2	+ .6
Appearance of 22s carded yarn with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	319	.400 ± .047	16.0	± 8.2	± 7.7
(2) Causticaire maturity and fineness substituted for alternative measures	6	319	.475 ± .043	22.6	± 7.9	± 7.4
Difference (2) - (1)	-	--	+ .075	+ 6.6	- .3	- .3
Appearance of all sizes of carded yarn with:						
(1) Usual 6 elements of raw-cotton quality and yarn size (control)	7	638	.657 ± .023	43.1	± 7.9	± 7.7
(2) Causticaire maturity and fineness substituted for alternative measures	7	638	.688 ± .021	47.3	± 7.6	± 7.4
Difference (2) - (1)	-	--	+ .031	+ 4.2	- .3	- .3
Strength of 22s carded yarn with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	319	.805 ± .020	64.8	± 8.7	± 7.6
(2) Causticaire maturity and fineness substituted for alternative measures	6	319	.819 ± .018	67.1	± 8.4	± 7.4
Difference (2) - (1)	-	--	+ .014	+ 2.3	- .3	- .2
Count-strength product of all sizes of carded yarn with:						
(1) Usual 6 elements of raw-cotton quality and yarn size (control)	7	638	.868 ± .010	75.4	±183.2	± 8.0
(2) Causticaire maturity and fineness substituted for alternative measures	7	638	.878 ± .009	77.2	±176.5	± 7.7
Difference (2) - (1)	-	--	+ .010	+ 1.8	- 6.7	- .3

1/ The usual 6 elements of raw-cotton quality included in the analyses were as follows: Grade index; upper half mean length; length uniformity ratio; fiber strength; Micronaire fiber fineness (weight per inch); and percentage of mature fibers (standard method).

2/ Unit varies with the dependent variable. For neps per 100 square inches of card web, the result is in terms of number of neps; for yarn appearance, it refers to index units of yarn appearance; for yarn strength, it is in units of pounds; and for count-strength product, it is in units of count-strength product.

3/ Absolute value of standard error ($\bar{S}$) divided by the mean value for the respective dependent variable, multiplied by 100.

Table 9.--Summary of statistical values obtained from multiple correlation analyses for six elements of raw-cotton quality, including alternative measures of fiber maturity and fiber fineness, with neps in card web, with yarn appearance, and with yarn strength, representing 309 selected cottons, crop year of 1952

Variables used in analysis, as--	Independent variables 1/	Observations	Value for-- Coefficient of correlation ($\bar{R}$)	Variance explained ($\bar{R}^2$ x 100)	Standard error of estimate ($\bar{S}$) Absolute	Relative
	Number	Number		Percent	2/	Percent 3/
Number of neps per 100 square inches of card web with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	309	0.645 ± 0.033	41.6	± 7.4	±47.0
(2) Causticaire maturity and fineness substituted for alternative measures	6	309	.629 ± .034	39.6	± 7.5	±47.8
Difference (2) - (1)	-	--	- .016	- 2.0	+ .1	+ .8
Appearance of 22s carded yarn with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	309	.580 ± .038	33.6	± 6.7	± 6.2
(2) Causticaire maturity and fineness substituted for alternative measures	6	309	.586 ± .037	34.4	± 6.7	± 6.1
Difference (2) - (1)	-	--	+ .006	+ .8	0.0	- .1
Appearance of all sizes of carded yarn with:						
(1) Usual 6 elements of raw-cotton quality and yarn size (control)	7	618	.710 ± .020	50.4	± 7.1	± 6.8
(2) Causticaire maturity and fineness substituted for alternative measures	7	618	.704 ± .020	49.5	± 7.2	± 6.9
Difference (2) - (1)	-	--	- .006	- .9	+ .1	+ .1
Strength of 22s carded yarn with:						
(1) Usual 6 elements of raw-cotton quality (control)	6	309	.849 ± .016	72.1	± 7.0	± 6.3
(2) Causticaire maturity and fineness substituted for alternative measures	6	309	.852 ± .016	72.6	± 6.9	± 6.2
Difference (2) - (1)	-	--	+ .003	+ .5	- .1	- .1
Count-strength product of all sizes of carded yarn with:						
(1) Usual 6 elements of raw-cotton quality and yarn size (control)	7	618	.909 ± .007	82.6	±146.7	± 6.6
(2) Causticaire maturity and fineness substituted for alternative measures	7	618	.912 ± .007	83.2	±144.3	± 6.5
Difference (2) - (1)	-	--	+ .003	+ .6	- 2.4	- .1

1/ The usual 6 elements of raw-cotton quality included in the analyses were as follows: Grade index; upper half mean length; length uniformity ratio; fiber strength; Micronaire fiber fineness (weight per inch); and percentage of mature fibers (standard method).

2/ Unit varies with the dependent variable. For neps per 100 square inches of card web, the result is in terms of number of neps; for yarn appearance, it refers to index units of yarn appearance; for yarn strength, it is in units of pounds; and for count-strength product, it is in units of count-strength product.

3/ Absolute value of standard error ($\bar{S}$) divided by the mean value for the respective dependent variable, multiplied by 100.

Table 10.--Relative net importance of six elements of raw-cotton quality, including alternative measures of fiber maturity and fiber fineness, to neps in card web, to yarn appearance, and to yarn strength, as evaluated by multiple correlation analysis, representing 319 cottons, crop year 1951

Variable	Observations	Analysis with 6 cotton-quality elements, including-- Percentage of mature fibers and Micronaire fineness: Rank	Percentage of mature fibers and Micronaire fineness: Beta coefficient 1/	Causticaire maturity and Causticaire fineness: Rank	Causticaire maturity and Causticaire fineness: Beta coefficient 1/
	Number				
Neps per 100 square inches of card web with:	319				
Fiber weight per inch		1	-0.771 ± 0.079	1	-0.410 ± 0.077
Grade index		2	+ .170 ± .050	4	+ .136* ± .051
Fiber maturity		3	+ .168* ± .075	2	- .288 ± .067
Upper half mean length		4	- .156* ± .053	5	- .127* ± .059
Length uniformity ratio		5	+ .108* ± .047	6	+ .099* ± .048
Fiber strength		6	+ .101* ± .051	3	+ .151* ± .051
Appearance of 22s carded yarn with:	319				
Fiber weight per inch		1	+ .278 ± .088	1	+ .311 ± .081
Fiber maturity		2	+ .106* ± .084	2	+ .207* ± .071
Upper half mean length		3	- .070* ± .059	6	+ .003* ± .063
Grade index		4	+ .067* ± .056	3	+ .065* ± .054
Fiber strength		5	+ .055* ± .057	5	+ .029* ± .054
Length uniformity ratio		6	- .025* ± .053	4	- .045* ± .051
Appearance of all sizes of carded yarn with:	638				
Yarn size		1	- .451 ± .031	1	- .449 ± .030
Fiber weight per inch		2	+ .329 ± .052	2	+ .313 ± .047
Grade index		3	+ .103 ± .033	4	+ .110 ± .031
Fiber maturity		4	+ .068* ± .049	3	+ .186 ± .042
Fiber strength		5	+ .042* ± .033	5	+ .019* ± .032
Upper half mean length		6	- .038* ± .035	6	+ .017* ± .037
Length uniformity ratio		7	+ .003* ± .031	7	- .009* ± .030
Strength of 22s carded yarn with:	319				
Upper half mean length		1	+ .663 ± .038	1	+ .580 ± .041
Grade index		2	+ .278 ± .037	2	+ .275 ± .035
Fiber strength		3	+ .122 ± .037	4	+ .151 ± .035
Fiber weight per inch		4	- .111* ± .058	3	- .247 ± .053
Length uniformity ratio		5	+ .059* ± .034	5	+ .072* ± .033
Fiber maturity		6	+ .046* ± .055	6	+ .070* ± .047
Count-strength product of all yarn sizes with:	638				
Yarn size		1	- .718 ± .021	1	- .720 ± .020
Upper half mean length		2	+ .586 ± .023	2	+ .513 ± .025
Grade index		3	+ .233 ± .022	3	+ .229 ± .021
Fiber weight per inch		4	- .106 ± .034	4	- .225 ± .031
Fiber strength		5	+ .104 ± .022	5	+ .129 ± .021
Fiber maturity		6	+ .050* ± .032	6	+ .073* ± .027
Length uniformity ratio		7	+ .047* ± .020	7	+ .058 ± .019

1/ The sign indicates the direction of the net contribution of the independent variable to the dependent variable.

* Statistically insignificant, being less than 3 times its standard error.

Table 11.--Relative net importance of six elements of raw-cotton quality, including alternative measures of fiber maturity and fiber fineness, to neps in card web, to yarn appearance, and to yarn strength, as evaluated by multiple correlation analysis, representing 309 cottons, crop year 1952

Variable	Observations	Analysis with 6 cotton-quality elements, including --: Percentage of mature fibers and Micronaire fineness: Rank	Beta coefficient 1/	Causticaire maturity and Causticaire fineness: Rank	Beta coefficient 1/
	Number				
Neps per 100 square inches of card web with:	309				
Fiber maturity		1	-0.396 ± 0.070	2	-0.295 ± 0.060
Fiber weight per inch		2	- .267 ± .070	1	- .412 ± .063
Fiber strength		3	- .173 ± .047	3	- .195 ± .048
Upper half mean length		4	+ .110* ± .045	6	+ .024* ± .055
Grade index		5	+ .083* ± .048	4	+ .090* ± .049
Length uniformity ratio		6	+ .023* ± .046	5	+ .049* ± .046
Appearance of 22s carded yarn with:	309				
Fiber weight per inch		1	+ .474 ± .075	2	+ .274 ± .065
Fiber maturity		2	+ .112* ± .075	1	+ .381 ± .062
Grade index		3	+ .094* ± .052	3	+ .076* ± .051
Fiber strength		4	- .045* ± .050	4	- .054* ± .050
Upper half mean length		5	- .021* ± .048	5	- .034* ± .057
Length uniformity ratio		6	+ .020* ± .049	6	+ .026* ± .048
Appearance of all sizes of carded yarn with:	618				
Yarn size		1	- .557 ± .030	1	- .556 ± .030
Fiber weight per inch		2	+ .429 ± .046	3	+ .232 ± .041
Grade index		3	+ .087* ± .032	5	+ .071* ± .032
Length uniformity ratio		4	+ .060* ± .030	4	+ .073 ± .030
Fiber strength		5	- .034* ± .031	6	- .043* ± .031
Upper half mean length		6	- .032* ± .031	7	- .041* ± .036
Fiber maturity		7	+ .026* ± .046	2	+ .272 ± .039
Strength of 22s carded yarn with:	309				
Upper half mean length		1	+ .700 ± .031	1	+ .596 ± .037
Fiber strength		2	+ .267 ± .032	2	+ .241 ± .032
Fiber maturity		3	- .209 ± .049	6	+ .040* ± .040
Grade index		4	+ .172 ± .034	4	+ .172 ± .033
Length uniformity ratio		5	+ .126 ± .032	5	+ .149 ± .031
Fiber weight per inch		6	+ .048* ± .049	3	- .226 ± .042
Count-strength product of all yarn sizes with:	618				
Yarn size		1	- .765 ± .018	1	- .767 ± .017
Upper half mean length		2	+ .564 ± .018	2	+ .480 ± .021
Fiber strength		3	+ .196 ± .018	4	+ .175 ± .018
Fiber maturity		4	- .153 ± .027	7	+ .037* ± .022
Grade index		5	+ .138 ± .019	5	+ .140 ± .018
Length uniformity ratio		6	+ .093 ± .018	6	+ .111 ± .017
Fiber weight per inch		7	+ .026* ± .027	3	- .187 ± .023

1/ The sign indicates the direction of the net contribution of the independent variable to the dependent variable.

* Statistically insignificant, being less than 3 times its standard error.

Table 12.--Comparison of statistical values obtained from multiple correlation analyses for six elements of raw-cotton quality, including Causticaire fineness and Causticaire maturity, with neps in card web, with yarn appearance, and with yarn strength, representing 319 cottons, crop of 1951, and 50 samples selected from them to cover the ranges of fineness and maturity by small and equal increments 1/

Variables used in analysis, as--	Independent variables 2/	Value for-- Coefficient of correlation ($\bar{R}$)	Variance explained ($\bar{R}^2$ x 100)	Standard error of estimate ($\bar{S}$) Absolute 3/	Relative Percent 4/
	Number		Percent		
Number of neps per 100 square inches of card web with:					
(1) Series of 319 cottons	6	0.560 ± 0.038	31.4	± 10.9	± 40.0
(2) 50 selected cottons 1/	6	.587 ± .094	34.4	± 16.0	± 51.2
Difference (2) - (1)	-	+ .027	+ 3.0	+ 5.1	+ 11.2
Appearance of 22s carded yarn with:					
(1) Series of 319 cottons	6	.475 ± .043	22.6	± 7.9	± 7.4
(2) 50 selected cottons 1/	6	.734 ± .066	53.9	± 6.9	± 6.5
Difference (2) - (1)	-	+ .259	+31.3	- 1.0	- .9
Strength of 22s carded yarn with:					
(1) Series of 319 cottons	6	.819 ± .018	67.1	± 8.4	± 7.4
(2) 50 selected cottons 1/	6	.822 ± .046	67.6	± 9.7	± 8.2
Difference (2) - (1)	-	+ .003	+ .5	+ 1.3	+ .8

1/ 25 cottons selected on the basis of equal steps of 0.1 microgram (weight per inch), by the Causticaire fineness method, over the range of 2.7 to 5.6 micrograms; and 25 cottons selected on the basis of equal steps of 1 percent maturity index, by the Causticaire maturity method, over the range of 64 to 85 percent maturity.

2/ The six elements of raw-cotton quality included in the analyses were as follows: Grade index; upper half mean length; length uniformity ratio; fiber strength; Causticaire fiber fineness (weight per inch); and Causticaire maturity index.

3/ Unit varies with the dependent variable. For neps per 100 square inches of card web, the result is in terms of number of neps; for yarn appearance, it refers to index units of yarn appearance; and for yarn strength, it is in units of pounds.

4/ Absolute value of standard error ($\bar{S}$) divided by the mean value for the respective dependent variable, multiplied by 100.

Table 13.--Comparison of statistical values obtained from multiple correlation analyses for six elements of raw-cotton quality, including Micronaire fiber fineness and percentage of mature fibers (standard method), with neps in card web, with yarn appearance, and with yarn strength, representing 319 cottons, crop of 1951, and 50 samples selected from them to cover the ranges of fineness and maturity by small and equal increments 1/

Variables used in analysis, as--	Independent variables 2/	Value for-- Coefficient of correlation ($\bar{R}$)	Variance explained ($\bar{R}^2$ x 100)	Standard error of estimate ($\bar{S}$) Absolute 3/	Standard error of estimate ($\bar{S}$) Relative 4/
	Number		Percent		Percent
Number of neps per 100 square inches of card web with:					
(1) Series of 319 cottons	6	0.576 ± 0.037	33.2	± 10.7	± 39.4
(2) 50 selected cottons 1/	6	.616 ± .089	37.9	± 15.6	± 49.8
Difference (2) - (1)	-	+ .040	+ 4.7	+ 4.9	+ 10.4
Appearance of 22s carded yarn with:					
(1) Series of 319 cottons	6	.400 ± .047	16.0	± 8.2	± 7.7
(2) 50 selected cottons 1/	6	.720 ± .069	51.8	± 7.1	± 6.6
Difference (2) - (1)	-	+ .320	+35.8	- 1.1	- 1.1
Strength of 22s carded yarn with:					
(1) Series of 319 cottons	6	.805 ± .020	64.8	± 8.7	± 7.6
(2) 50 selected cottons 1/	6	.815 ± .048	66.5	± 9.8	± 8.3
Difference (2) - (1)	-	+ .010	+ 1.7	+ 1.1	+ .7

1/ 25 cottons selected on the basis of equal steps of 0.1 microgram (weight per inch), by the Causticaire fineness method, over the range of 2.7 to 5.6 micrograms; and 25 cottons selected on the basis of equal steps of 1 percent maturity index, by the Causticaire maturity method, over the range of 64 to 85 percent maturity.

2/ The six elements of raw-cotton quality included in the analyses were as follows: Grade index; upper half mean length; length uniformity ratio; fiber strength; micronaire fiber fineness (weight per inch); and percentage of mature fibers (standard method).

3/ Unit varies with the dependent variable. For neps per 100 square inches of card web, the result is in terms of number of neps; for yarn appearance, it refers to index of yarn appearance; and for yarn strength, it is in units of pounds.

4/ Absolute value of standard error ($\bar{S}$) divided by the mean value for the respective dependent variable, multiplied by 100.

Table 14.--Comparison of statistical values obtained from multiple correlation analyses for six elements of raw-cotton quality, including alternative measures for fiber fineness and maturity, with neps in card web, with yarn appearance, and with yarn strength, representing 50 samples selected from the 319 cottons, crop of 1951, to cover the ranges of fineness and maturity by small and equal increments 1/

Variables used in analyses, as--	Value for--: Independent variables 2/	Coefficient of correlation ($\bar{R}$)	Variance explained ($\bar{R}^2$ x 100)	Standard error of estimate ($\bar{S}$): Absolute 3/	Standard error of estimate ($\bar{S}$): Relative
	Number		Percent		Percent 4/
Number of neps per 100 square inches of card web with:					
(1) Usual 6 elements of raw-cotton quality (control)	6	0.616 ± 0.089	37.9	± 15.6	± 49.8
(2) Causticaire maturity and fineness substituted for alternative measures	6	.587 ± .094	34.4	± 16.0	± 51.2
Difference (2) - (1)	-	- .029	- 3.5	+ .4	+ 1.4
Appearance of 22s carded yarn with:					
(1) Usual 6 elements of raw-cotton quality (control)	6	.720 ± .069	51.8	± 7.1	± 6.6
(2) Causticaire maturity and fineness substituted for alternative measures	6	.734 ± .066	53.9	± 6.9	± 6.5
Difference (2) - (1)	-	+.014	+ 2.1	- .2	- .1
Strength of 22s carded yarn with:					
(1) Usual 6 elements of raw-cotton quality (control)	6	.815 ± .048	66.5	± 9.8	± 8.3
(2) Causticaire maturity and fineness substituted for alternative measures	6	.822 ± .046	67.6	± 9.7	± 8.2
Difference (2) - (1)	-	+.007	+ 1.1	- .1	- .1

1/ 25 cottons selected on the basis of equal steps of 0.1 microgram (weight per inch), by the Causticaire fineness method, over the range of 2.7 to 5.6 micrograms; and 25 cottons selected on the basis of equal steps of 1 percent maturity index, by the Causticaire maturity method, over the range of 64 to 85 percent maturity.

2/ The usual six elements of raw-cotton quality included in the analyses were as follows: Grade index; upper half mean length; length uniformity ratio; fiber strength; micronaire fiber fineness; and percentage of mature fibers (standard method).

3/ Unit varies with the dependent variable. For neps per 100 square inches of card web, the result is in terms of number of neps; for yarn appearance, it refers to index units of yarn appearance; and for yarn strength, it is in units of pounds.

4/ Absolute value of standard error of estimate ($\bar{S}$) divided by the mean value for the respective dependent variable, multiplied by 100.

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